ONR REPORT ACR-64
USNSAM MONOGRAPH 5

ANIMALS AND MAN IN SPACE

A CHRONOLOGY AND ANNOTATED BIBLIOGRAPHY THROUGH THE YEAR 1960

Dietrich E. Beischer and Alfred R. Fregly

U.S. Naval School of Aviation Medicine
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FOREWORD

Several investigators interested in preparing biological experiments to be conducted high in the earth's atmosphere or in space have commented upon the difficulty of locating in the literature the results of prior experiments. This was brought to the attention of the Armed Forces-National Research Council Committee on Bio-Astronautics, and an effort was begun by that Committee to bring together in a single document the results of experiments conducted before 1961. The Committee was terminated before this effort could be completed. The U.S. Navy, through the Office of Naval Research, sponsored the completion of this compilation utilizing the facilities and staff of the U.S. Naval School of Aviation Medicine which were made available through the courtesy of CAPT C. P. Phoebus, MC, USN. The resulting comprehensive compilation is designed to be useful to investigators in the preparation of future biological experiments in space.

J P Pollard

J. P. POLLARD
Captain, MC, USN
Special Assistant for Medical and Allied Sciences
Office of Naval Research

PREFACE

Since man has actually accomplished the historical task of ballistic flight (Alan Shepard, May 5, 1961, and Gus Grissom, July 21, 1961), and of orbital flight (Yuri Gagarin, April 12, 1961, and Gherman Titov, August 6, 1961), a compilation of events which have contributed to these brilliant feats is considered essential. Achievements in this field reflect numerous scientific efforts of many disciplines within the biological community. It appears timely to make this wealth of information readily available in the form of an annotated bibliography prepared for investigators in the bioscientific fields in general.

The bibliography is expected to serve a number of purposes: It should give the busy investigator ready access to the widely scattered literature, including partly buried material, such as technical reports of limited access. Awareness of all past approaches and achievements in bioastronautics should help to evaluate their effectiveness. Finally, such understanding and knowledge should serve as a guide in decisions for future planning of biological experiments in space and to prevent costly repetitions.

However, questions about the extent of animal experiments in space and human travel in these regions are not only of scientific interest. The general public, and especially administrators of the considerable financial means necessary to carry out such programs, should be aware of the historical background. The bibliography may thus be of considerable service in publicizing the biomedical aspect of space travel.

The actual preparation of animal or man for a flight into space represents an application of a wealth of experience drawn from biological and other scientific fields. Therefore, it was considered helpful to have the main part of the bibliography preceded by a list of sources of pertinent information related to bioastronautics. The bibliographies, books, and technical reports cited in the first chapter outline the framework into which the material of the following chapters should be set.

The material of these chapters is grouped around the technical means of conveyance into space: balloons, rockets, missiles, satellites, and rocket-propelled aircraft. Since it is not the purpose of this report either to review or to survey the present "state of the art," but rather to present and highlight the chronology of circumscribed developments and accomplishments, the material in each chapter is presented in tabular form. Each table provides the key to the annotated bibliography which follows. The citations in Chapters II and III are given in alphabetical order, with a numerical sequence within each letter sequence (A-1, A-2, B-1, B-2 for Chapter II, and a-1, a-2, b-1, b-2 for Chapter III). These alphabetical-numerical designations are used in the tables and in Appendix 1 for referencing the pertinent articles. To make the bibliographies of Chapters II and III completely independent of each other, a few entries in Chapter II are repeated in Chapter III, if reference is made to both balloon and rocket flights. The citations given in Chapter I are not numbered; when citations from Chapter I appear in the tables, they appear by author's name. This arrangement serves also as an author index. The varying and partly arbitrary length of the annotations reflects merely the prerogatives of the authors rather than the merits of any given individual research effort or research program. Original reports and publications exclusively were abstracted. The tabulated material and the bibliography used together should provide for easy referencing and cross-referencing of each experiment as conducted individually or by a research team.

A list of abbreviations is added as Appendix 1. This list gives the usual designations of military and civilian organizations doing work related to biomedical research.

Appendix 2 might be considered as a selective subject index, presenting a list of all biological material prepared for or actually flown in space experiments using different means of conveyance. For convenience, the items in this appendix are also listed in alphabetical order. It is interesting to note that the six most frequently mentioned biological specimens cited in the literature are, in descending order, (1) human subjects, (2) mice, (3) primates, (4) dogs, (5) Neurospora, and (6) Drosophila. Man's creditable showing as an experimental subject in space flights during these mere beginnings of space research has its explanation in the ingenuity of balloon-research pioneers.

The authors strived to make the bibliography as complete as possible. They will appreciate errors or inaccuracies being brought to their attention. Similarly, receipt of publications which

relate particularly to experiments reported herein but not yet evaluated will be welcomed for expediting a revision of the material at a later date.

Opinions and conclusions contained in this article are the authors'. They should not be construed as necessarily reflecting the view or the endorsement of the Navy Department. Many individuals, organizations, and activities have contributed during the assembly of this bibliography by making available reports and by advice freely given. The authors would like to express their gratitude to the many persons who have helped them, and they would like to mention especially General Don Flicklinger, Commander Malcom D. Ross, Dr. Sam F. Seeley, Colonel David G. Simons, and Otto C. Winzen.

CONTENTS

CHAPTER I

BACKGROUND

INTRODUCTION

The general bibliography presented in this first chapter represents merely a sample listing of the background information which may be consulted in helping to solve specific problems of flights involving biological experiments. These information sources of necessity span a wide range, from technical information on the vehicles to the most subtle problems in manned space flight, including "space psychology and sociology." Most of the background information has its solid roots in aviation medicine, developed in winged flight and readily extended to space flight. The authors did not strive for completeness in this chapter. However, in their experience the material listed here was found to be most helpful in searches for specific information. The third part of this chapter, on technical publications and periodical articles, includes suggestions and preparations for biological payloads which, for different reasons, have not been used up to this date.

GENERAL BIBLIOGRAPHY

Bibliographies

Air Crew Equipment Laboratory, "A bibliography of psychophysiological studies relevant to space and orbital flight," NAMC-ACEL-441, Naval Air Material Center, Philadelphia, Oct. 1960

Lists 582 entries (on 3 x 5 in. file-card forms) based on a literature review through April, 1960 of psychological, physiological, and environmental reports pertinent to man's role in space and orbital flight.

Air University Library, "Earth satellites," Special Bibliography No. 118, Supplement No. 1. Maxwell AFB, 1958

Lists 127 selected references in Air University Library including books, documents, and periodicals.

Armed Services Technical Information Agency, "Bio-astronautics: An ASTIA report bibliography," AD-211775, Arlington, Virginia, 1959

Covers biological problems of space flight as represented by ASTIA holdings through 1958. Lists 919 references.

Army Library, "Guided missiles. A selected list of titles," Special Bibliography No. 4, Dept. of the Army, Adjutant General's Office, April 1956

This bibliography represents a listing of 800 pertinent titles.

Army Library, "Military aspects of space exploration. A selected list of titles, "Special Bibliography No. 16, Dept. of the Army, Adjutant General's Office, June 1958

Some 300 titles of carefully selected unclassified literature on the military implications of space exploration, excluding deliberately the broader aspects which involve the overall scientific and nonscientific trends and activities.

Banghart, F. W., and Pattishall, E. G., "Human factors at extreme altitudes: synopsis and bibliography," HQARDC-TR-60-7, Division of Educational Research, Univ. of Virginia, March 1960

The synopsis and bibliography include the following paragraphs: (1) Space 1956-1959, (2) Space Medicine, (3) Ecology, (4) Behavior and Performance, (5) Acceleration and Deceleration, (6) Weightlessness, (7) Radiation, (8) Instrumentation, Monitoring and Communication, (9) Selection and Training, and Appendix.

Benton, M., "Earth satellites, guided missiles, rockets, and space flight: a bibliography of books and periodical articles," Wilson Library Bulletin 32:412-419 (Feb. 1958)

An annotated list of selected publications covering the period 1936 to October 1957, with emphasis given to items of recent date.

Benton, M., "The literature of space science and exploration," Bibliography No. 13, AD 210057, U. S. Naval Research Laboratory, Sept. 1958

An annotated list of 2274 titles arranged by chronological periods, alphabetically by author. Twenty-seven of the titles cover pre-1940 material; 70 cover the period 1940-1949; the remainder are arranged by year, beginning in 1950 and extending through early 1958.

Benton, M., "Artificial satellites, a bibliography of recent literature," Jet Propulsion 28:301, (1958)

An annotated listing of 340 references brings up to date the bibliography on "A History of the Artificial Satellite," by R. Krull, Jet Propulsion 26:369-383 (1956)

Department of the Army, Headquarters, "Missiles, rockets, and satellites," Pamphlet No. 70-5-1 to 8. Washington, D. C., 1958 to 1960

Eight annotated bibliographies, for the period 1957-Sept. 1960, covering various aspects of the subject, and titled as follows: I. "USSR," II. "United States," III. "Great Britain, France, and Other Free Countries of the World," IV. "Technology: Means and Methods," and V. "Earth Satellites and Space Exploration." This bibliography is continued as follows: Missiles, Rockets, and Space in War and Peace (70-5-6), Missiles, Rockets, and Space Vehicles 1959-1960 (70-5-7), and USSR: Missiles, Rockets, and Space Effort, A Bibliographic Record 1956-1960 (70-5-8).

Estep, R., "A space bibliography through 1958," AU-283-58-RSI, Maxwell AFB, Air University, Sept. 1959

Lists 1832 references with subject and author indexes. Covers items in books and periodicals available at Air University, especially for the period from 1930 through 1958.

Goodman, R. D., "Psychological and social problems of man in space—a literature survey," ARS Journal 31(7):863-872 (1961)

It is the purpose of this bibliography to bring together the reports, books, and periodical articles published through the early part of 1961 dealing with the specific area of behavioral science related to space flight, or as it is sometimes called "space psychology." This area includes problems of confinement, isolation, sensory deprivation, weightlessness, psychological assessment and training, motivation and morale, emotional stability, boredom and fatigue, performance under stress, and work load.

Gowdey, C. W., and Pearce, J. W., "A selected bibliography of the open literature on aviation medicine 1945-1955," Defence Research Board, Ottawa, Canada, July 1955

Emphasis has been placed on subjects which lend themselves more to basic than to applied research. No references to technical and project reports are included.

Hendrickson, R. N., "Bibliography on space medicine," AECU-3914, Atomic Energy Commission Technical Information Service Extension, Oak Ridge, Mar. 1958

This list of references is confined. It may be used to supplement other reference sources.

Jacobius, A. J., and Wilkins, M. J., "Aviation medicine - an annotated bibliography," Vol. 1, 1952 Literature, AD-108861, Library of Congress, 1956

The first annual cumulation of the bibliography on the subject prepared at the Library of Congress under plans to include all available published book and periodical literature and unclassified reports issued from 1951 to 1956. Author and subject indexes are provided.

Jacobius, A. J., Wilkins, M. J., Kassianoff, L., Slie, R. B., and Whitehead, S. L., "Aviation medicine - an annotated bibliography," Vol. 2, 1953 Literature, St. Paul, Aero Medical Association, 1959

The second volume on the subject, considerably increased in size. Subject coverage: (1) history and general aspects of aviation medicine, (2) aviation physiology, (3) pathology and pharmacology of aviation, (4) aviation psychology, (5) preventive medicine and sanitation, (6) special problems in high altitude and space flight, and (7) miscellaneous problems.

Jacobius, A. J., Kenk, R., Marrow, E., Plavnieks, I. M., Voulgaris, K. and Davis, L. D., "Aerospace medicine and biology, an annotated bibliography," (formerly Aviation Medicine), Vol. 3, chiefly 1954 literature, AD 248102, Library of Congress, 1960

The third annual volume to provide comprehensive coverage of the aerospace-medical and bioastronautical literature. In addition to journal articles, reports and monographs published during 1954, it incorporates items published in 1952 or 1953 not included in the preceding volumes.

Jacobius, A. J., Kenk, R., and others, "Aerospace medicine and biology, an annotated bibliography," (formerly Aviation Medicine), Vol. IV, 1955 literature, AD 258191, Library of Congress, 1961

This volume continues the effort made in earlier volumes. The series appears indispensable for literature search in the field of aerospace medicine.

Klier, S., and Linskey, J. W., "Selected abstracts from the literature on stress," TR-NAVTRADEVCEN 565-1, U. S. Naval Training Device Center, Port Washington, New York, Nov. 1960

This report is the result of a comprehensive literature search for information on stress pertinent to the training problem. It includes abstracts of 397 selected articles.

Mullins, W. S., "Russian scientific literature: a guide to sources, translations and translators," Armed Forces-NRC Committee on Bio-Astronautics, National Academy of Sciences - National Research Council, undated

A general guide without reference to specific scientific areas.

National Library of Medicine, "Bibliography of space medicine," No. 617, and Bibliography Series No. 21., U. S. Department of Health, Education and Welfare, Public Health Service, 1958

References for this bibliography have been selected from a search of the indexes and catalogs of the National Library of Medicine, and from examination of the principal aviation, aviation medicine, and astronautical publications; they are arranged in broad subject classes, in inverse chronological order, alphabetically by author within the years.

Rand Corporation, Technical Staff, "An annotated bibliography of Rand space flight publications," RM-2113-1, AD-216108, Santa Monica, California: The Rand Corporation, 1958, revised 1959

A list of all Rand studies pertaining to space flight available to properly qualified industrial contractors and commercial organizations.

Robinette, J. C., editor, "Bibliography on aeromedical research with abstracts," WADD, Aerospace Medical Laboratory, Dec. 1959

Compilation of abstracts of technical documentary reports issued by the Aerospace Medical Laboratory, WADD, from 1957 through 1959. The major areas comprising the Laboratory's mission are behavioral sciences, biomedical sciences, and engineering as related to human factors in aircraft design and survival equipment.

Monographs

Adams, C. C., "Space flight," New York:McGraw-Hill, 1958

This book is designed to give a complete, well-rounded account of (1) the history and background of the astronautical sciences, (2) the many subsidiary fields that compose these sciences, (3) detailed information on many of the most important world-wide developments of astronautical significance. It is further intended to offer exceptionally complete coverage of introductory space-flight material, assess the present state of the art, and present a penetrating look into the future potentials of astronautics.

Armstrong, H. G., editor, "Aerospace medicine," Baltimore: The Williams and Wilkins Co., 1961

The successor to an earlier book entitled "The Principles and Practice of Aviation Medicine," it is the only complete treatise in existence at present on the subject of aerospace medicine. A great array of diverse subject matter is arranged in an orderly, logical sequence of 32 chapters written with the highly specialized knowledge and experience of 21 contributing authors. The information contained has been culled from some 1100 scientific

journals, periodicals, and technical reports, many of which are published in foreign languages. This volume has been written primarily for the use of the student and the practitioner of aerospace medicine

Benson, O. O., Jr., and Strughold, H., editors, "Physics and medicine of the atmosphere and space," New York: Wiley, 1960

The proceedings of the Second International Symposium on the Physics and Medicine of the Atmosphere and Space held at San Antonio, Texas, Nov. 10-12, 1958, sponsored by the School of Aviation Medicine, Aerospace Medical Center (ATC), Brooks AFB, Texas, with the assistance cf the Southwest Research Institute of San Antonio. This volume records the material presented to the approximate 800 scientists, physicians, and engineers who attended the meeting and comprises 42 papers by 48 authors for the purpose of assembling all of the data pertinent to manned space flight, and of cementing the scientific bonds among the physical scientists, engineers, and the bioscientists mutually concerned with the scientific challenge in the conquest of space.

Buckheim, R. W., and Staff of Rand Corporation, "Space handbook: Astronautics and its applications," New York: Random House, 1959, and Washington, D. C.: U. S. Government Printing Office, 1959

This handbook was prepared for the Select Committee on Astronautics and Space Exploration, House of Representatives, to meet the need for an authoritative study in lay terms of the state of the art of space flight in the present and definitely foreseeable future. It contains a good historical review of the development of animal space flight in the USSR.

Gantz, K. F., "Man in space: The United States Air Force program for developing the spacecraft crew," New York: Duell, Sloan and Pearce, 1959

A book intended to give a professional view of the current investigations of the U. S. Air Force into the problems of putting its aerospace crews into outer flight. Chapters were written by top Air Force scientists and ranking officers at work with the research and planning and, with one exception, were originally composed for article publication in a special "human factor" issue and in other issues of Air University Quarterly Review.

Hanrahan, J. S. and Bushnell, D., "Space biology: the human factors in flight," New York: Basic Books, Inc., 1960

An historical survey of research accomplishments from the earliest times which have led to the present sophistication in the revolutionary field of space biology. It is not a textbook in space biology, but rather a description of present knowledge concerning the physiological aspects of manned space flight. In addition to highlighting present understanding of space flight problems, from waste disposal to weightlessness, some indications are offered of the steps to current accomplishments. Moreover, an attempt is made to identify the individual scientists who have made important contributions to this progress.

Krieger, F. J., "Behind the sputniks: a survey of Soviet space science," Washington, D. C.: Public Affairs Press, 1958

Delineates the history of the development of astronautics in Russia from the turn of the century up to the launching of the first artificial satellite.

Ley, W., "Missiles, rockets, and space travel," New York: The Viking Press, 1957

Particularly valuable for its historical material, it is devoted to the past, present and future of rockets.

Mallan, F., "Men, rockets and space rats," New York:Julian Messner, Inc., 1955

The story of some of the contemporary aeronautical pioneers behind some of the great contributions to aeronautics during the past few decades.

Newell, H. E., Jr., "High altitude rocket research," New York:Academic Press, Inc., 1953

This book has as its primary aim the presentation of the principal results of upper-air rocket research which have been published in the open literature from approximately 1946 to 1953. The scope of the review is limited to rocket-borne experiments.

Piccard, A., "Earth, sky and sea," New York:Oxford University Press, 1956

The unique story of a scholar, physicist, and master technician who recounts his courageous triumphs of penetrating the stratosphere and descending to the depths of the sea. It is primarily an account of the invention of the stratospheric balloon and the subsequent adoption of its principle to the building of the bathyscaphe.

Sells, S. B., and Berry, C. A., editors, "Human factors in jet and space travel," New York: The Ronald Press, 1961

A comprehensive view of the human factors of high-performance flight, it is intended to give physicians, physiologists, engineers, flight crews, and other interested persons a better perspective of what is involved in putting man in a foreign environment and then insuring his well-being there. A second purpose is to provide physicians with a reference book on aviation medicine and related human-factor problems.

Simons, D. G., with Schanche, D. A., "Man high," Garden City, N. Y.:Doubleday 1960

A personal account of the three Manhigh experiments is rendered in this highly readable presentation. With new insights concerning both the accomplishments and the technical-scientific difficulties, and of the individuals deeply involved in this story behind the stories, it is replete with information not available in any other document.

White, C. S., and Benson, O. O., Jr., "Physics and medicine of the upper atmosphere, a study of the aeropause," Albuquerque:The University of New Mexico Press, 1952

The proceedings of a symposium held at San Antonio, Texas, November, 1951, and sponsored by the Air University School of Aviation Medicine, Randolph Field, Texas. These proceedings represent a classical collection of papers initiating the new period of "space medicine."

Technical Publications And Periodical Articles

Air University, "Bioastronautics - advances in research," AD 226473, Randolph AFB, Texas, USAFSAM, 1959

In this publication fifteen special progress reports are published which deal with problems applicable in rocket flight and satellite flight (chapters on "Bio-Paks" and "Primates in

Space"). Others report about progress in fields which will be of usefulness in more advanced space operations (chapters on "Photosynthetic Gas Exchanges. . . . " and "Man in Space").

Archibald, E. R., Ward, W. E., Darling, P. H. and Mosely, J. D., "Chimpanzee temperature-humidity tolerance test No. 1, " TN-60-11. HAFB, New Mexico:AFMDC, 1960

Describes the effects of a temperature-humidity test conducted July 28, 1959 on a restrained young male chimpanzee, weighing 36 pounds, in an environmental test chamber. Primary objective of the test was to determine the feasibility of conducting temperature-humidity tolerance tests on large biological specimens. The results demonstrated that such tests are feasible. The subject was exposed to an environment of 85°F and 80 percent relative humidity for the eight-hour test period. Pulse rate, respiration rate, electrocardiogram, rectal temperature, galvanic skin resistance, environmental oxygen depletion, and carbon dioxide accumulation were monitored continuously. Instrumentation procedures, general test techniques, and experimental design are described. The subject lost two pounds, or six percent of his initial body weight.

Aviation Medical Acceleration Laboratory, "Bioprobe, development and study with, " letter report concerning life support system, NADC-MA-L6007, Johnsville, Pa. :NADC, 1960

Some technical details of the bioprobe and the results of test runs with rats are described.

Aviation Medical Acceleration Laboratory, "Biosatellite, development and study with, " letter report concerning life support system, NADC-MA, Johnsville, Pa. :NADC, 1960

The development of an environmental system will permit animal study under the simulated satellite conditions excepting zero gravity. The work described in the report concerns this environmental simulator.

Aviation Medical Acceleration Laboratory, "Status report on animal satellite, " letter report concerning, AE-1412, Johnsville, Pa. :NADC, 1958

Progress which has been made in the biosatellite program since its initiation on February 27, 1958, is listed. The preparations for this animal satellite which has not been put in orbit were made with cooperation of the Franklin Institute

Banghart, F. W., "Biological payloads in space flight, " ARDC-TR-58-58, AD 204761, U. of Virginia, Division of Educational Research, 1958

Reports the joint efforts of a working group assembled at the U. of Virginia, Sept. 2-5, 1958, to discuss useful biological payloads and desirable bioscience experiments to be carried on in vehicles capable of space flight. The major objective of the working group centered around biological experiments which would provide data from which the feasibility of a manned space flight could be determined. This document summarizes the accomplishment of that objective, and is presented under four major categories: (1) behavioral factors, (2) instrumentation factors, (3) ecological factors, (4) physiological effects.

Brock, F. J., "Acceleration shock protection experiments using live pigs, " St. Louis, Missouri:McDonnell Aircraft Corporation, (undated)

Presents the results of acceleration shock experiments on live pigs and describes analytical evaluation of these data for a fuller understanding of the phenomena and for leading to an approximate method of predicting the magnitude of some of the effects of acceleration

shock. Test subjects were three-month-old, female, Yorkshire pigs. The aluminum honeycomb energy absorption system tested had a high energy absorption capacity, approximately 20,000 ft lbs/lb, and is considered to have been effective in preventing acceleration-shock damage of the pigs. The analytical method reported herein is considered an aid to understanding shock response and may be used to predict human response to acceleration shock.

Graybiel, A., Beischer, D. E., Hixson, W. C., Moss, A. J., and Stullken, D. E., "Medical aspects of the Project Mercury recovery program," Report prepared for NASA, SAM P-14, U. S. N. School of Aviation Medicine, Pensacola, Florida, 1960

This report deals with the care and handling of the astronaut following impact and is presented in two parts. Part I is a methodical treatment of the principal elements in medical planning of the recovery program. Part II is a specific plan for a manned flight of three orbits.

Henry, J. P., "Project Mercury, status of the animal test program," NASA Project Mercury Working Paper No. 158, NASA Space Task Group, Langley Field, Va., October 1960

Outlines the origin and purposes of the animal test program, details of the Mercury capsule animal program underway at AMFL, HAFB, prelaunch facilities at Cape Canaveral, operational aspects, information anticipated from the animal flights, and future research possibilities of the program. Appendices contain the animal-monitoring and flight-data plans and list the personnel involved in the animal program.

Krieger, F. J., "Soviet astronautics," P-1437, Santa Monica, Calif.:The Rand Corp., 1958

This lecture describes briefly the long and active history of Soviet interest in space flight, leading up to the launching of Sputniks I and II. A discussion of Soviet technical and popular literature on space flight is included.

Krieger, F. J., "The Soviet ballistic missile and space flight program," P-1388. Santa Monica, Calif.:The Rand Corp., 1958

A brief history of Soviet space flight accomplishments through Sputnik II. Some logical developments of the Soviet ballistic-missile and space-flight programs are traced.

Newell, H. E., Jr., "U. S., Russian space efforts compared." Aviation Week 71:36, 37, 41, 43, 47, 49-50 (Dec. 1959)

Both the U. S. and Soviet satellites and space probes have produced valuable scientific results. Some spectacular discoveries and achievements are shown in table form. In addition to the more spectacular output, satellite and space-probe flights are turning out a steady flow of information and results that build up gradually an impressive advancement of mankind's knowledge of the earth and outer space. This review relates the impression that U. S. and USSR scientists are at about equal stages of advancement.

Simons, D. G., "Areas of current space medical research," chapter in "Vistas in Astronautics," Alperin, M., and Stern, M., editors, pp. 299-303, New York:Pergamon Press, 1958

Effects of heavy-ray particles, the design of sealed cabins, the effects of weightlessness, and the problems of reentry into the atmosphere are briefly discussed.

Vitro Laboratories, "Applications of manned stratospheric laboratories," minutes of sessions held at the 27th Annual Meeting of the Institute of Aeronautical Sciences at New York, Jan. 29, 1959, Silver Spring, Md.:Vitro Laboratories, 1959

The first session was concerned chiefly with the instrumentation of manned balloons in terms of the scientist, who accompanies the balloonist, as a nonexpendable servomechanism to perform duties which would be difficult to relegate to automatic computing equipments. Topics discussed and the participants were: Introduction, D. H. Menzel; "Requirements for high resolution photography of planets," G. H. De Vaucouleurs; "Infra-red and ultra-violet measurements at high altitude," J. Blamont; "Proposed observations of the Martian atmosphere," M. D. Ross; "Geophysical researches of stratospheric laboratory," W. D. Roberts and G. A. Newkirk, Jr.; "Measurement of atmospheric, dispersion and vertical motion," H. T. Mantis; "Observation of severe storms from above," B. Vonnegut; panel discussion. The second session focused attention on medical problems and opportunities for study, particularly with balloon-borne platforms. Topics discussed and the participants were: Introduction, - N. L. Barr; "Training in preparation for Manhigh I," J. Kittinger; "Cosmic ray detection by visual scintillations," H. Yagoda; The balloon-borne capsule as a space flight trainer," E. E. Benson; "Infra-red spectroscopy from balloons and the possibility of some observations on the biosphere," D. M. Gates; "The strato-laboratory as a system testing platform," J. R. Smith; panel discussion.

Vitro Laboratories, "The Strato-Lab as a research vehicle," Technical Report No. 117. Silver Spring, Md.:Vitro Laboratories, 1959

To determine what are the research, testing, or system activities which require Strato-Lab for their fulfillment and which would be essential to the national interest, Vitro Laboratories, under contract to ONR, canvassed leading scientific, industrial, and government laboratories. Over 500 persons were approached in connection with the canvass, and over 100 responses were obtained, all indicating an interest in the Strato-Lab concept. A large number made concrete suggestions for stratospheric research programs. The results of the survey are summarized. It has been the intention of this work to obtain a sufficiently broad cross section of possible investigations to establish the value of the Strato-Lab concept and to determine the design requirements for an all-purpose cabin system for future research. Through this program the scientific community has been made aware of the capabilities of high-altitude balloon systems as research vehicles. An appendix reports on the Boulder, Colorado, conference (Oct. 31, 1958) on the use of balloons for research in physics, astrophysics, and geophysics.

Vitro Laboratories, "Strato-Lab cabin system functional requirements," Technical Report No. 118, Silver Spring, Md.:Vitro Laboratories, 1959

This report is largely an extension of work performed under Phase I (Vitro Laboratories Technical Report No. 117). Two general conclusions have been drawn regarding the design aims and functional limitations which should be of primary consideration in the development of a manned stratospheric laboratory. These are: (1) the gross cabin system should not exceed 4000 to 5000 lb; (2) the design of the cabin should permit flight without pressure suits at full sea-level internal pressure. Listed in this report in tabular form are the functional requirements imposed on the Strato-Lab in the following areas: flight-operations requirements, environmental requirements, experimental research requirements.

Vitro Laboratories, "Strato-Lab cabin system," Engineering specifications, Technical Report No. 119, Silver Spring, Md.:Vitro Laboratories, 1959

The engineering specifications for the Strato-Lab gondola system are developed, based on Reports Nos. 117 and 118.

Winzen Research, Inc., "Proposal for an airborne laboratory of space physiology," Proposal No. 11112-P, Minneapolis, Minn., 1957

In the belief that this is the time to explore the problems of space flight as they relate to the human pilot and passenger, Winzen Research presents this proposal for a manned space station designed to explore those human factors with which the future of space medicine will be preoccupied for many years to come. This proposal outlines the company's approach to the design, development, construction, and operation of such a space laboratory and describes a number of possible uses for this new research tool.

Winzen, O. C., "Ten years of plastic balloons," Proceedings of the VIIIth International Astronautical Congress, Barcelona, 1958, pp. 436-459, Springer-Verlag, Wien, 1958

The year 1957 marks the 10th anniversary year of the plastic stratosphere balloon. During their brief history the new balloons have become reliable vehicles for upper-atmosphere research and operational work. From their early duties as delicate carriers of light loads, they have now been perfected to the point at which they can be used for the routine launching of light loads to altitudes in excess of 120, 000 ft and heavy loads to altitudes of 80, 000 ft and higher. Gross weights of over 5, 000 lb have been flown to date, and balloons with volumes in excess of three million cubic feet are being built on a production basis. The proposed five-million-cubic-foot balloon can carry a gross load of 10, 000 lb to 85, 000 ft, or twice that load to 70, 000 ft. The plastic balloon is also a practical tool for the investigation of human factors of space flight and manned space laboratories for high-altitude studies. Most spectacular applications are the recent manned high-altitude flights on USAF-Winzen Research Project Manhigh, as well as as the ONR-Winzen Research, Inc. Rockoon launchings, in which balloons were used as platforms for the launching of rockets, boosting their altitude capability substantially. This paper presents some details of balloon applications and takes a look into the future of balloons.

* * *

CHAPTER II

BIOLOGICAL AND BIOMEDICAL EXPERIMENTS ON BALLOON FLIGHTS

INTRODUCTION

Unmanned Balloons

On Sept. 19, 1783, a balloon launched a sheep, a cock, and a duck to an altitude of 1500 ft and returned them to earth unharmed from the world's first successful air-passenger flight. This first flight was merely a flight-survival study.

Renewed use of balloons for biological experiments started approximately in 1947, when Beal exploited the superior qualities of polyethylene balloons as a means of assessing effects of cosmic radiation on plant seeds. These initial experiments were followed in 1950 by successful balloon flights of mammals, conducted by the United States Air Force in an attempt to evaluate the biological effect of cosmic radiation. These flights replaced earlier biological rocket experiments, which were stopped when the supply of V-2 rockets had been exhausted. The revival of the old art of ballooning provided a vehicle for biological loads which allowed much longer exposure times at high altitude than the rocket but limited experiments to about a 20-mile altitude.

Approximately ninety known unmanned balloon launches carrying biological payloads to high altitudes are recorded in the following tabular presentation. The number of yearly launches reached a maximum in 1953, with 23 balloons carrying animals. The initial difficulties in providing adequate environmental control and recovery of the payload were mastered gradually. During the period from February 1955, through April 1956, the art was improved to a degree, when among nineteen flights, nine were completely and three partially successful. In time, the increase in payload allowed the inclusion of a larger variety of biological specimens. The selection of these specimens demonstrates a nearly exclusive interest in the effects of cosmic radiation on living matter, with black mice and Neurospora leading the list.

The original mere handful of dedicated balloon researchers was joined by a host of biological investigators, as reflected in the number of biological payloads designed for the Jig I flight series in 1958 and the Astro series in 1959 and 1960. The decrease in balloon launches of animals to only one in 1957 may be explained partly by a concentration on manned balloon flight. By 1956 enough information had been accumulated as a result of animal flights to make feasible a program of extended manned balloon flights to high altitudes. These flights started a new chapter of balloon exploration, namely manned flight reaching and surpassing 100, 000 ft.

Manned Balloons

In 1783, P. de Rozier ascended in a Montgolfier-type balloon to become the first human balloon passenger. More notorious in those days was M. J. P. Blanchard, who by 1793 had become the idol of fascinated balloon-watching assemblies in Europe by virtue of his numerous ascents in the preceding ten years. On Jan. 10, 1793, he made the first successful air voyage in America, and on the occasion of his forty-fifth ascension he performed a biomedical experiment amidst a series of "high altitude" investigations. He reported the findings faithfully in an autobiographical report of his flight. Of particular interest in that document is the following account:

> I passed on to the observation which Doctor Rush had requested me to make upon the pulsation of the artery, when I should be arrived at my greatest height. I found it impossible to make use of the

quarter-minute glass which he had provided for that purpose, but I supplied its place by an excellent second-watch; and the result of my observation gave me 92 pulsations in the minute (the average of 4 observations made at the place of my highest elevation) whereas on the ground I had experienced no more than 84 in the same given time, average of 4 observations: difference 8 pulsations more at the height of 5812 English feet, where I then was.*

That a human, rather than an animal, was the initial subject of such a physiological experiment no doubt reflects in part the limited technology (e.g., no telemetry capabilities) of that era. However, while telemetered physiological responses have become a routine aspect of modern day manned balloon ascents, it seems worth noting that to this day no known balloon-borne animals have been subjects per se of continuous physiological monitoring. The consistent concentration upon man throughout the history of ballooning seems noteworthy.

The tabular presentation on manned balloon flights might be considered to reflect two main developmental periods. An early era started with the ascents of Piccard in the early 1930's and came to a conclusion with Stevens' and Anderson's Explorer II flight in 1935. The flights in this period demonstrated man's capability to navigate the stratosphere up to altitudes of about 70,000 ft and were primarily a test of survival. After a 21-year lapse in activity, a second period, which may be considered as extending to the present, was initiated by the ascent of Ross and Lewis in Strato-Lab I. The achievements of the Strato-Lab and Manhigh series by the United States Navy and Air Force are part of this stage. These flights developed a wealth of information on travel and survival of man at altitudes close to and above 100,000 ft. They also promoted the idea of establishing laboratory facilities above the air ocean. The manned balloon may continue to solve fruitfully and economically many questions of space travel, e.g., testing of equipment, astronomical observations, cosmic ray studies, and space-crew selection. The future successes of manned space missions, by whatever method of flight, will owe primary allegiance to the courage and foresight of the mere handful of pioneers represented in the following accounts of manned balloon experiments.

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* M.J.P. Blanchard, "The First Air Voyage in America," Philadelphia: The Penn Mutual Life Insurance Co., 1943.

TABULAR CHRONOLOGY

Biological Experiments in Unmanned Balloon Flights - U. S. A.

Flight Designation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
First	Nov. 18 1947	Stagg Field U. of Chicago Illinois	Seeds - Lilium amabile Palibin; L. pumilum DC; L. regale Wils; and Brassica hirta Moench	To slightly over 100,000 ft; seeds recovered from Lake Erie on Nov. 21, 1947, thoroughly soaked, planted immediately.	Beal	B-2
Second	Mar. 9 1948	Stagg Field U. of Chicago Illinois	Seeds - Lilium amabile Palibin; L. pumilum DC; L. regale Wils; and Brassica hirta Moench	To 65,000 ft; remained over 60,000 ft a little over 1-1/2 hr; returned to investigator and planted on Mar. 12, 1948.	Beal	B-2
Fourth	Oct. 13 1948	Stagg Field U. of Chicago Illinois	Seeds of Scarlet Globe radish and grains of Radium Brand spring rye	To approx. 65,000 ft; (no info. was available on the length of exposure at this elevation); seeds returned and planted on Oct. 16, 1948.	Beal	B-2
Preliminary, unnumbered AMFL flight	Sep. 8 1950	HAFB (41°N geomagnetic latitude)	14 or 16 white mice ("Albert" capsule)	To 47,000 ft; mice recovered dead, due to capsule depressurization and leakage, 7 hr after launch.	AML WADC	A-5 A-6 S-3*
Preliminary, unnumbered AMFL flight	Sep. 28 1950	HAFB	8 white mice ("Albert" capsule)	To 97, 000 ft; 3 hr and 40 min. Mice recovered alive and unharmed First successful animal flight.	AML WADC	A-5 A-6 S-3
Preliminary, unnumbered AMFL flight	Jan. 18 1951	HAFB	Mice ("Albert" capsule)	Balloon burst at 45,000 ft; capsule recovered 2 hr after impact.	AML WADC	A-5 A-6 S-3
AMFL 2	Aug. 23 1951	HAFB	Hamsters (Minnesota capsule)	To 59,000; 2 hr Balloon failure during ascent; no data.	AMFL† Campbell	A-5 A-6 S-3

*The major source of this compilation through AMFL flight No. 39.

(Table Continues)

†All succeeding flights conducted under auspices of AMFL.

Biological Experiments in Unmanned Balloon Flights - U. S. A. (Continued)

Flight Desig-nation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investi-gators	Refer-ences
AMFL 3	Sep. 5 1951	HAFB	Hamsters	To 97,000 ft; at 90,000 ft for 4 hr; delayed recovery; no data.	Camp-bell	A-5 A-6 S-3
AMFL 4	Sep. 7 1951	HAFB	Hamsters	To 94,000 ft; above 90,000 ft for 4-1/2 hr; recovery alive and in good con-dition 45 min after impact.	Camp-bell	A-5 A-6 C-1 C-2 S-3
AMFL 7	Feb. 20 1952	HAFB	Anesthetized cat; 3 hamsters	To 103,600 ft; 43 hr; 2-month delay in recovery precluded useful data.	Camp-bell	A-5 A-6 S-3
AMFL 8	Feb. 27 1952	HAFB	Anesthetized cat; 3 hamsters (Minnesota capsule)	Balloon burst at 54,000 ft; all animals killed on impact.	Camp-bell	S-3
AMFL 13	Apr. 24 1952	HAFB	Animals (Minnesota capsule)	To 87,000 ft; 28 hr; recovery delayed 4 months. 1st successful 28-hr tracking mission.	Camp-bell	S-3
AMFL 14	May 15 1952	HAFB	Fruit flies	To 87,200 ft; 23-1/2 hr; recovery delay of 2-1/2 months; no data.	AMFL	A-5 A-6 S-3
AMFL 18	Jul. 16 1952	HAFB	2 dogs (NYU capsule)	To 92,000 ft; 10-1/2 hr; Capsule lost pressurization; animals recovered dead 30 min after impact.	Murray	A-5 A-6 M-2 S-3
AMFL 20	Feb. 12 1953	HAFB	7 Hamsters	Between 96,500 & 82,500 ft; 22 hr; recovered alive at NAAS Whiting Field, Milton, Fla. even though capsule open-ing delayed 6 days. No brain pathology attributable to cos-mic radiation.	Camp-bell	A-6 A-7 C-1 C-2 S-3 S-5
AMFL Moby Dick 1	Feb. 19 1953	Vernalis NAS, Calif.	600 Drosophila melanogaster	All flies dead.	AMFL	A-6 A-7 S-3 S-5

(Table Continues)

Biological Experiments in Unmanned Flights - U. S. A. (Continued)

Flight Designation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
AMFL Moby Dick 2	Feb. 20 1953	Vernalis NAS, Calif.	600 Drosophila melanogaster	All flies dead.	AMFL	A-6 A-7 S-3 S-5
AMFL Moby Dick 3	Feb. 22 1953	Vernalis NAS, Calif.	600 Drosophila melanogaster	12 flies survived from their 469 progeny, no indication of translocations was observed.	AMFL	A-6 A-7 S-3 S-5
AMFL Moby Dick 4	Feb. 24 1953	Vernalis NAS, Calif.	600 Drosophila melanogaster	Flies not recovered.	AMFL	A-6 A-7 S-3 S-5
AMFL Moby Dick 5	Feb. 25 1953	Vernalis NAS, Calif.	600 Drosophila melanogaster	All flies dead.	AMFL	A-6 A-7 S-3 S-5
AMFL Moby Dick 6	Feb. 26 1953	Vernalis NAS, Calif.	600 Drosophila melanogaster	Package never returned.	AMFL	A-6 A-7 S-3 S-5
AMFL 21	Mar. 12 1953	HAFB	30 mice; 6 hamsters; 500 flies	To 84,000 ft; 36 hr 20 min; capsule environmental control inadequate for animal survival.	Campbell	A-6 A-7 S-3 S-5
AMFL 22	Mar. 18 1953	HAFB	2 dogs (NYU capsule)	Balloon burst at 34,000 ft; packages descended by parachute; capsule recovery delayed; animals perished.	Murray	A-6 A-7 M-2 S-3 S-5
AMFL 25	Apr. 12 1953	Tillamook, Oregon	Flies; black mice; hamsters	To 30, 000 ft; recovery delayed; no data.	Campbell	A-6 A-7 S-3 S-5
AMFL 27	Apr. 24 1953	HAFB	2 dogs (NYU capsule)	To 85,000 ft; animals died shortly after takeoff for unexplainable reasons.	Murray	A-6 A-7 M-2 S-3 S-5

(Table Continues)

Biological Experiments in Unmanned Flights - U. S. A. (Continued)

Flight Desig-nation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investi-gators	Refer-ences
AMFL 28	May 5, 1953	HAFB	Hamsters; black mice; onions	To 86,000 ft; recovery delayed.	Chase Campbell Krebs	A-6 A-7 C-3 S-2 S-5
AMFL 29	Jun. 19 1953	Great Falls Air Base, Montana	Onions, reflown on flight 30; anesthetized cat; 6 hamsters; 1000 flies	Above 85,000 ft; 10 hr; animals recovered alive; 500 Drosophila to be reflown on flight 30.	Campbell Krebs	A-6 A-7 S-2 S-3 S-5
AMFL 30	Jun. 23 1953	HAFB	Onions from flight 29; anesthetized cat; 10 black mice; all the hamsters from flight 29; 1000 flies	Altitude unknown; flight remained north of 55° geomagnetic latitude for 10 hr; cat recovered alive; mice and hamsters recovered dead; flies survived but number insufficient to conduct further experiments.	Campbell Krebs	A-6 A-7 C-1 C-2 S-2 S-3 S-5
AMFL 31	Jul. 20 1953	Great Falls Air Base, Montana	One anesthetized cat; black mice; hamsters; fruit flies	To 85,000 ft; capsule never recovered.	Campbell	A-6 A-7 S-3 S-5
AMFL 32	Jul. 24 1953	Great Falls Air Base, Montana	Cat; hamsters; mice; flies	To 56,000 ft; capsule never recovered.	Campbell	A-6 A-7 S-3 S-5
AMFL 33	Sep. 21 1953	HAFB	2 dogs with track plates (NYU capsule)	To 85,000 ft; 10 hr; packages recovered one week later.	Murray	A-6 A-7 M-2 S-3 S-5
AMFL 34	Oct. 26 1953	Pierre, S. Dakota	14 hamsters; 30 white mice; 1000 fruit flies; 13 black mice; 3 red, 1 brown, & 2 white onions	To 90,000 ft; 28-1/2 hr; capsule depressurized during flight; crash landing of capsule; no animals recovered alive.	Campbell Krebs	A-6 A-7 S-3 S-5

(Table Continues)

Biological Experiments in Unmanned Balloon Flights - U.S.A. (Continued)

Flight Desig-nation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investi-gators	Refer-ences
AMFL 35	Nov. 1 1953	Pierre, S. Dakota	14 hamsters; 30 white mice; 1000 fruit flies; 13 black mice; 3 red, 1 brown, & 2 white onions	To 2000 ft; all equipment recovered, most of animals survived.	Campbell Krebs	A-6 A-7 S-3 S-5
AMFL 36	Nov. 3 1953	Pierre, S. Dakota	14 hamsters; 30 white mice; 1000 fruit flies; 13 black mice; 3 red, 1 brown, & 2 white onions	Balloon failed at 30,000 ft; 7 hamsters, 6 white mice, and 9 black mice survived; flies killed on impact.	Campbell Krebs	A-6 A-7 S-3 S-5
AMFL 37	Nov. 10 1953	Pierre, S. Dakota	16 black mice; 20 white mice; onions; flies; 14 hamsters	To 90,000 ft; 6-1/2 hr; all fruit flies; 1 hamster, 3 black mice and 9 white mice died from hyperthermia.	Campbell Cibis Krebs	A-6 A-7 C-3 S-2 S-3 S-5 S-18
AMFL 38	Nov. 13 1953	Pierre, S. Dakota	7 white mice; 12 black mice; 12 hamsters flown on flight 37; 500 fruit flies; onions - plus 4 black mice, 13 white mice, and 2 additional hamsters not previously exposed	To 90,000 ft; 18-1/2 hr; all mammals survived; some flies recovered alive.	Campbell Chase Cibis Krebs	A-6 A-7 C-3 S-2 S-3 S-5 S-18
AMFL 39	Dec. 16 1953	HAFB	Skin from 10 mice; barley seeds	To 88,000 ft; botanical material successfully exposed and recovered.	Simons Eugster	A-6 A-7 E-2 E-3 S-3 S-4 S-5
AMFL 41	Feb. 23 1954	HAFB	2 dogs (NYU capsule)	To 60,000 ft; animals survived until shortly before recovery.	Simons Murray	A-6 A-7 H-4 M-2 S-5 S-10 S-25

(Table Continues)

Biological Experiments in Unmanned Flights - U. S. A. (Continued)

Flight Desig-nation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investi-gators	Refer-ences
AMFL 43	Mar. 12 1954	HAFB	2 dogs (NYU capsule)	To 75,000 ft; specimens perished due to delayed recovery.	Simons Murray	A-6 A-7 H-4 M-2 S-5 S-10 S-25
AMFL 44	Jun. 24 1954	HAFB	Mice	Balloon destroyed by wind during launch.	Simons Chase AFIP	A-6 A-7 H-4 S-5 S-10 S-25
AMFL 45	Jul. 7 1954	Fleming Field, Minn. (57-1/2°N geo. latitude)	Mice; Neurospora; cats	To 79, 000 ft; all biol. specimens recovered in good condition.	Simons AFIP Chase Stone	A-6 A-7 H-4 S-5 S-10 S-25
AMFL 46	Jul. 15 1954	Sault Sainte Marie, Mich.	Dry corn & barley seeds; 3 monkeys; 111 white mice; 31 black mice; radish seeds; Neurospora; 1 rat; 6 pieces of human skin; 19 fertilized chicken eggs	To 96, 750 ft; most animals survived the flight satisfactorily.	Simons Eugster AFIP Krebs Cibis Strughold	A-6 A-7 E-2 E-3 H-4 L-2 S-5 S-8 S-10 S-24 S-25
AMFL 47	Jul. 18 1954	Sault Sainte Marie, Mich.	2 monkeys; 94 white mice; 26 black mice; radish seeds; Neurospora; Eugster's material re-exposed from flight 46; 1 rat; 6 pieces of human skin; dry corn & barley seeds; 9 fertilized chicken eggs	To 94, 300 ft; most animals did not survive this flight.	Simons Eugster Krebs Cibis Strughold	A-6 A-7 E-2 E-3 H-4 L-2 S-5 S-8 S-10 S-24 S-25
AMFL 48	Jul. 21 1954	Sault Sainte Marie, Mich.	61 white mice; 42 black mice; radish seeds; Neurospora; 3 rats; 8 fertilized chicken eggs	Balloon failed at 50, 000 ft; capsule free-fell; all animals perished.	Simons Krebs Cibis Strughold	A-6 A-7 H-4 L-2 S-5 S-8 S-10 S-24 S-25

(Table Continues)

Biological Experiments in Unmanned Balloon Flights - U.S.A. (Continued)

Flight Designation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
AMFL 49	Jul. 25 1954	Sault Sainte Marie, Mich.	50 white mice; 36 black mice; 1 rabbit; Neurospora; 1 rat; radish seeds; dry corn & barley seeds; 9 fertilized chicken eggs	To 95,000 ft; over 92,000 ft for 32 hr; animals succumbed to capsule depressurization.	Simons Eugster Krebs Cibis Strughold.	A-6 A-7 E-3 H-4 L-2 S-8 S-10 S-24 S-25
AMFL 50	Jul. 29 1954	Sault Sainte Marie, Mich.	2 monkeys; 67 white mice; 27 black mice; radish seeds; Neurospora; 1 rat; dry corn and barley seeds; 8 fertilized chicken eggs	To 97,000 ft; above 92,000 ft for 33-1/2 hr; all animals recovered satisfactorily.	Simons Eugster Krebs Harlow Chase Cibis Strughold Campbell	A-6 A-7 C-4 C-5 E-3 H-1 H-4 L-2 S-5 S-8 S-10 S-18 S-24 S-25
AMFL 51	Aug. 2 1954.	Sault Sainte Marie, Mich.	2 monkeys; 89 white mice; 32 black mice; radish seeds; Neurospora; 8 fertilized chicken eggs	To 96,000 ft; all specimens recovered satisfactorily.	Simons Harlow Chase Cibis Strughold Campbell	A-6 A-7 C-4 C-5 H-1 H-4 L-2 S-5 S-8 S-10 S-18 S-24 S-25
AMFL 52	Aug. 6 1954	Sault Sainte Marie, Mich.	63 white mice; 39 black mice; 15 rats; Neurospora; radish seeds; 10 fertilized chicken eggs	To 95,400 ft; above 90,000 ft for 17 hr; recovered safely; all animals survived.	Simons Chase Cibis Strughold Campbell	A-6 A-7 C-4 C-5 H-4 L-2 S-5 S-8 S-10 S-18 S-24 S-25

(Table Continues)

Biological Experiments in Unmanned Balloon Flights - U. S. A. (Continued)

Flight Desig-nation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investi-gators	Refer-ences
AMFL 53	Aug. 10 1954	Sault Sainte Marie, Mich.	75 white mice; 15 black mice; 15 rats; 1 guinea pig; radish seeds; Neurospora; 12 fertilized chicken eggs	To 89,800 ft; above 85,000 ft for 25 hr; recovery delayed 10 days; all specimens perished.	Simons Cibis Strughold	A-6 A-7 H-4 L-2 S-5 S-8 S-10 S-24 S-25
AMFL 54	Oct. 12 1954	HAFB	92 white mice; 49 black mice; (control specimens for northern flights)	To 93,200 ft; above 83,000 ft; for 24 hr; some mice died, apparently from overcrowding.	Simons Stone Chase	A-6 A-7 C-4 C-5 H-4 S-4 S-5 S-8 S-10 S-18 S-24 S-25
AMFL 55	Feb. 2 1955	HAFB	101 white mice; 14 black mice; 3 guinea pigs (control flight for AMFL specimens)	Capsule parachuted safely; animals recovered alive.	Simons et al.	A-6 A-7 H-4 S-5 S-10 S-24 S-25
AMFL 56	Feb. 3 1955	HAFB	101 white mice; 14 black mice; 3 guinea pigs (control flight for AMFL specimens)	To 40,000 ft; capsule not recovered.	Simons et al.	A-6 A-7 H-4 S-5 S-10 S-24 S-25
AMFL 57	May 12 1955	HAFB	Tissue cultures	Balloon failed; free fall from very high altitude; specimens apparently undamaged.	Simons et al.	A-6 A-7 H-4 S-5 S-10 S-24 S-25
AMFL 59	Jun. 7 1955	HAFB	51 black mice; 32 white mice; 2 guinea pigs; 8 tissue cultures; Artemia eggs	Balloon failure, just above ground; all biological specimens recovered.	Simons et al.	A-6 A-7 H-4 S-5 S-10 S-24 S-25

(Table Continues)

Biological Experiments in Unmanned Balloon Flights - U. S. A. (Continued)

Flight Designation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
AMFL 60	Jun. 17 1955	HAFB	4 black mice; 73 white mice; 2 guinea pigs; tissue cultures; Artemia eggs	To floating altitude; animals died because of delayed recovery.	Simons et al.	A-6 A-7 H-4 S-4 S-5 S-6 S-10 S-24 S-25
AMFL 61	Jul 18 1955	South St. Paul, Minn.	Artemia eggs; Neurospora crassa; tissue cultures	Above 110, 000 ft; 7-1/2 hr; all biol. specimens recovered in good condition.	Simons Haymaker Stone	A-6 A-7 H-4 S-5 S-6 S-7 S-10 S-24 S-25 W-1
AMFL 62	Jul. 19 1955	South St. Paul, Minn.	Neurospora; tissue cultures	To 130, 000 ft; above 120, 000 ft for 6hr 50 min; moderate damage to specimens due to depressurization.	Simons et al.	A-6 A-7 H-4 S-5 S-6 S-10 S-24 S-25 W-1
AMFL 63	Aug. 1 1955	International Falls, Minn.	91 black mice; 4 Artemia samples; Neurospora crassa; onion seeds; snapdragon seeds; grasshopper eggs	To 119, 000 ft; 25 hr; all biol. specimens recovered satsifactorily.	Simons Walton Chase Stone	A-6 A-7 C-4 C-5 H-4 S-5 S-10 S-18 S-24 W-1
AMFL 64	Aug. 5 1955	International Falls, Minn.	12 guinea pigs; 4 Artemia samples; cytological specimens from flight 63; Neurospora crassa; dry corn & barley seeds	To 115, 000 ft; average altitude of 114, 000 ft maintained through 26-hr flight; all animals died due to excessive capsule temperature.	Simons Walton Stone Eugster	A-6 A-7 H-4 S-5 S-10 S-24 S-25 W-1

(Table Continues)

Flight Designation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
AMFL 65	Aug. 8 1955	International Falls, Minn.	11 guinea pigs; 4 Artemia samples; cytological specimens from flights 63 and 64	To 126,000 ft; good altitude maintenance through 27-hr flight; biological specimens recovered in good condition.	Simons Walton Chase	A-6 A-7 C-4 C-5 H-4 S-5 S-7 S-10 S-18 S-24 S-25 W-1
AMFL 66	Aug. 11 1955	International Falls, Minn.	93 black mice; 4 Artemia samples	To 92,000 ft; excellent altitude maintained during 25-hr flight; recovery of animals in excellent condition.	Simons Walton Chase	A-6 A-7 C-4 C-5 H-4 S-5 S-10 S-18 S-24 S-25 W-1
AMFL 67	Aug. 22 1955	International Falls, Minn.	Capsule 1: 93 mice; Artemia eggs; cytological specimens from flights 63, 64 & 65; Neurospora crassa Capsule 2: 93 white mice; 24 tissue cultures	Above 110,000 ft for 5 hr; 105,000 ft - 110,000 ft for 6 hr 50 min; above 80,000 ft. for 22 hr; one capsule depressurized, killing animals; other animals recovered in good condition.	Simons Walton Lebish Haymaker Stone Hild	A-6 A-7 H-4 L-1 S-5 S-10 S-24 S-25 W-1
AMFL 68	Aug. 31 1955	International Falls, Minn.	107 C-57 black mice; 3 guinea pigs; 12 tissue cultures; Artemia eggs; cytological specimens from flights 63, 64, 65 & 67; (cultures of cat cerebellum, HeLacells, L-strain connective tissue cells)	Above 120,000 ft; for 4 hr 45 min; all animals died due to delayed recovery.	Simons Hild Walton Pomerat Lebish	A-6 A-7 H-2 H-3 H-4 L-1 S-5 S-10 S-24 S-25 W-1
AMFL 69	Sep. 1 1955	International Falls, Minn.	1 guinea pig; 10 C-57 black mice; 8 tissue cultures	To 120,000 ft; cut-down failed; capsule not recovered.	Simons Chase	A-6 A-7 C-5 H-2 H-4 S-5 S-10 S-24 S-25 W-1

(Table Continues)

Biological Experiments in Unmanned Ballon Flights - U. S. A. (Continued)

Flight Desig-nation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investi-gation	Refer-ences
AMFL 70	Sep. 12 1955	South St. Paul, Minn.	32 C-57 black mice; 3 guinea pigs; 23 tissue cultures	To 130,000 ft; all animals recovered in excellent condition.	Simons Haymaker Krogh Schummelfeder Hild Pomerat	A-6 A-7 H-3 H-4 L-1 S-5 S-10 S-24 S-25 W-1
AMFL 71	Sep. 20 1955	South St. Paul, Minn.	73 C-57 mice; 40 Bagg strain mice	To 115,000 ft; cut-down failed; recovery not effected.	Simons et al.	A-6 A-7 H-4 S-5 S-10 S-24 S-25 W-1
AMFL 72A	Nov. 29 1955	HAFB	52 mice; 5 guinea pigs; Neurospora; barley seeds	Balloon destroyed by wind at launch.	Simons et al.	A-6 A-7 H-4 S-5 S-10 S-25
AMFL 72B	Feb. 11 1956	HAFB	70 mice; 5 guinea pigs; Neurospora; Drosophila (control flight for International Falls flights)	To 115,000 ft; all animals recovered in good condition.	Simons et al.	A-6 A-7 H-4
AMFL 73	Apr. 10 1956	HAFB	Neurospora (control flight for previous Northern flights, International Falls, Minn.)	To 85,700 ft; all specimens recovered in good condition.	Simons et al.	A-6 A-7 H-4
Manhigh Capsule Test	Nov. 1956	HAFB	Guinea pig	Not known.	Simons Haymaker	A-7
Manhigh Capsule Temperature Test	Apr. 14 1957	South St. Paul, Minn.	10 guinea pigs; mice; Neurospora; egg albumin	To 103,500 ft; all animals recovered in good condition; mice lost day after recovery due to heater failure at storage place.	Simons Haymaker DeBusk Yagoda	A-6 A-7 H-4 S-10 S-17

(Table Continues)

Biological Experiments in Unmanned Ballon Flights - U. S. A. (Continued)

Flight Desig-nation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investi-gators	Refer-ences
Jig 1 Flight A	Jul. 19 1958	Interna-tional Falls, Minn.	1 monkey; goldfish; Drosophila larvae; Neurospora; frogs; Pedospora & other genera of molds and algae; various micro-biological systems; lens epithelium; pota-toes; onions; leaves; petals; rats	Balloon (5 million cu ft) ruptured at launch.	Simons Hay-maker Corkhill Hoffman DeBusk Chase Yagoda Eugster Pipkin Spense Camer-meyer von Sallman Bahn Krebs Maurer Tessmer Halberg	C-7 H-4 Han-rahan and Bushnell
Jig 1 Flight B	Jul. 30 1958	Crosby, Minn.	1 monkey; goldfish; Drosophila larvae; Neurospora; frogs; Pedospora & other genera of molds and algae; various micro-biological systems; lens epithelium; potatoes; onions; leaves; petals; rats	To 50, 000 ft; balloon ruptured in jet stream; biological speci-mens sustained no damage.	Simons Hay-maker Corkhill Hoffman DeBusk Chase Yagoda Eugster Pipkin Spense Camer-meyer von Sallman Bahn Krebs Maurer Tessmer Halberg	C-7 H-4 Hanra-han and Bushnell
Jig 1 Flight C	Aug. 7 1958	Crosby, Minn.	Same as Jig 1 Flight B	Balloon burst at 63, 000 ft; biolog-ical specimens sustained no ap-parent damage.	Same as Jig 1 Flight B	C-7 H-4 Hanra-han and Bushnell
ASTRO 59-1	Jun. 30 1959	Sioux Falls, S. Dakota	Neurospora	Launched sucess-fully, but balloon lost during a thunderstorm; not recovered.	Stone DeBusk	Hewitt (per-sonal com-muni-cation)

(Table Continues)

Biological Experiments in Unmanned Ballon Flights - U. S. A. (Continued)

Flight Designation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
ASTRO 59-2	Aug. 5 1959	International Falls, Minn.	Neurospora crassa N-51; Neurospora ascospores; barley seeds	To 127,000 ft for 13 hours.	Simons DeBusk Stone Eugster	S-20
ASTRO 59-3	Aug. 19 1959	International Falls, Minn.	Neurospora crassa N-51; Tissue culture (embryonic rat dorsal root ganglion cells); Neurospora ascospores; barley seeds	To 118,000-ft altitude; capsule decompression prevented significant biological results.	Simons Pomerat DeBusk Stone Eugster	S-20
ASTRO 60-1	Apr. 12 1960	Minneapolis, Minn.	Neurospora; mosquito eggs; barley seeds; Neurospora ascospores	Above 95,000 ft for 2-1/2 hr.	USAFSAM DeBusk Patterson Eugster Stone	Personal Communication
ASTRO 60-3	May 17 1960	Minneapolis, Minn.	Neurospora; mosquito eggs; Neurospora ascospores	Above 95,000 ft for 2-1/2 hr.	USAFSAM DeBusk Patterson Stone	Personal Communication
ASTRO 60-6	Jul. 17 1960	Bemidji, Minn.	Ludwigia palustris; tissue cultures of HeLa; conjunctiva; bone marrow; Chlorella; E. coli; Neurospora; mosquito eggs; white & black mice	Maximum altitude 134,000 ft; 11 hr 40 min.	ARDC-SAM Wilks Kratzberg Phillips Davis Stone Hewitt DeBusk Chase Haymaker Patterson	S-22
ASTRO 60-7	Jul. 23 1960	Bemidji, Minn.	Ludwigia palustris; tissue cultures of HeLa; conjunctiva; bone marrow; Chlorella; E. coli; Neurospora; mosquito eggs; white & black mice	Maximum altitude 132,000 ft; at altitude 11 hr 59 min.	ARDC-SAM Wilks Kratzberg Pillips Davis Stone Hewitt DeBusk Chase Haymaker Patterson	S-22

(Table Continues)

Biological Experiments in Unmanned Ballon Flights - U. S. A. (Continued)

Flight Desig-nation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investi-gators	Refer-ences
ASTRO 60-8	Jul. 29 1960	Bemidji, Minn.	Ludwigia palustris; tissue cultures of HeLa; conjunctiva; bone marrow; Chlorella; E. coli; Neurospora; mosquito eggs	Maximum altitude 144,000 ft; at altitude 11 hr 9 min.	Same as flight ASTRO 60-7	S-22
ASTRO 60-9	Aug. 5 1950	Bemidji, Minn.	Same as flight ASTRO 60-7	Maximum altitude 142,000 ft; at altitude 11 hr.	Same as flight ASTRO 60-7	S-22

Biological Experiments in Unmanned Balloon Flights - Switzerland

Flight Designation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
Series 1	Beginning Summer 1953	Payerne, Switzerland (Geomagnetic latitude 50°)	240,000 eggs of Artemia salina	To 75,000 ft; ("the eggs having suffered central hits by a heavy primary showed a hatching rate of 2% as compared to controls. The existence of dominant lethal factors has been proved.").	Eugster Waeffler Roost	E-1 E-2
Series IV	Beginning Summer 1953	Payerne, Switzerland	Excised, precancerous pieces of dog skin.	To 75,000 ft; 4-5 hr; "a) basal cells of skin showing tracks. Basal-celled carcinoma arising from the pigmented cells of the stratum germinativum of the surface epithelium and from the hair matrices. b) development of granulation tissue at the loci corresponding to hits (piece of skin from right auricle)."	Eugster Waeffler Roost	E-1 E-2
Series VIII	Beginning Summer 1953	Payerne, Switzerland	Excised pieces of human skin	To 75,000 ft; 5 hr; demonstration of distinct CR tracks with nuclear fission figures with a diameter exceeding 450 microns.	Eugster Waeffler Roost	E-1 E-2
Series XX & XXI	Beginning Summer 1953	Payerne, Switzerland	Pieces of skin removed aseptically with a dermatone during plastic surgery following amputation of the breast	To 70,000 - 71,000 ft; 6 hr; at 2 points marked hits; small granulomas developed after 2 months.	Eugster Waeffler Roost	E-2
Series XXII & XXIV	Beginning Summer 1953	Payerne, Switzerland	Piece of skin ($4\ cm^2$) removed aseptically from upper left arm and right side of the thorax, medial to the right maximilla	To 70,000 ft; after about 12 months, a light brown pigmentation showed up in the two small tumors. Every month the pigmentation become a darker brown.	Eugster Waeffler Roost	E-2

Biological Experiments in Manned Balloon Flights

Flight Designation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
FNRS*	Aug. 18 1932	Zurich, Switzerland	A. Piccard M. Cosyns	To 53,153 ft; successful.	Piccard Cosyns	P-1 W-5 Piccard
USSR	Feb. 20 1933	Moscow, USSR	Prokoviet B. Godunow	To 60,697 ft; successful.	Prokoviet Godunow	W-5
Century of Progress	Nov. 20 1933	Akron, Ohio	T. G. W. Settle C. L. Fordney	To 61,238 ft; successful.	Settle Fordney	W-5
C-0 AX-1 OSSOAWIACHIM	Jan. 30 1934	Moscow, USSR	Fedosienko Wasienko Usyskin	To 72,180 ft; during descent suspension lines tore, gondola free-fell; crew perished.	Fedosienko Wasienko Usyskin	W-5
Explorer 1	Jul. 28 1934	Rapid City, S. Dakota	W. E. Kepner A. W. Stevens O. A. Anderson barberry spores	To 60,615 ft; balloon tore on descent and free-fell; crew saved by their personal parachutes.	Nat. Geog. Society U.S. Army Air Corps Kepner Stevens Anderson Meier	G-2 S-26 W-5
Century of Progress	Oct. 23 1934	Detroit, Mich.	Dr. and Mrs. Piccard	To 57,580 ft; successful.	Piccard Piccard	W-5
Explorer II	Nov. 11 1935	Rapid City, S. Dakota	A. W. Stevens O. A. Anderson Drosophila melanogaster	To 72,395 ft; flight sucessful beyond expectations.	Nat. Geog. Society U. S. Army Air Corps Jollos Meier	A-1 A-2 A-3 G-2 J-1 M-1 N-1 S-1 W-5
Strato-Lab 1	Nov. 8 1956	Rapid City, S. Dakota	M. D. Ross M. L. Lewis	To 76,000 ft; flight permaturely terminated by malfunctioning balloon valve; feasibility of the system and accomplishment of project demonstrated satisfactorily.	U. S. Navy ONR Barr Shepp Yarczower Standaert	A-4 B-1 R-1 R-2 R-4 R-5 R-6 R-7 S-1 W-2 W-5 W-7

(Table Continues)

*Fonds National Belge de la Recherche Scientifique

Biological Experiments in Manned Balloon Flights (Continued)

Flight Designation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
Manhigh 1	Jun. 2 1957	Fleming Field, S. St. Paul, Minn.	J. W. Kittinger	To 95, 500 ft; a human error in connecting the automatic oxygen-control valve resulted in early termination of flight.	USAF AMFL Simons Stapp	A-6 A-7 S-10 S-13 S-14 W-5 W-9 Simons with Schanche
Manhigh II	Aug. 19 1957	Portland Mine, Crosby, Minn.	D. G. Simons Neurospora	To 101, 516 ft; sucessful; flight lasted 32 hr 10 min; established world altitude & endurance record; flight remained at 101, 000 ft. for 5 hr.	USAF, AMFL Simons Stapp Archibald DeBusk Yagoda	A-6 A-7 A-8 S-9 S-10 S-11 S-12 S-13 S-14 S-15 S-16 S-17 S-19 S-23 W-3 W-4 W-5 W-6 Y-1
Strato-Lab 2	Oct. 18 1957	Crosby, Minn.	M. D. Ross M. L. Lewis	To 85, 700 ft; flight established an unofficial world altitude record for a 2-man flight.	US Navy, ONR Ross Lewis Barr, et al.	A-4 B-1 R-4 R-6 R-7 W-5 W-10
Strato-Lab 3	Jul. 26 1958	Crosby, Minn.	M. D. Ross M. L. Lewis <u>Drosophila melanogaster</u>	To 82, 000 ft;first flight to stratosphere in a sealed cabin which contained its own complete, artificial atmosphere and which maintained essentially a sea-level environment.	US Navy, ONR Pipkin Sullivan Yagoda	P-2 R-4 R-6 W-8 Y-1
Manhigh III	Oct. 8 1958	Holloman AFB, New Mexico	C. M. McClure, III	To 99, 700 ft; capsule overheated; flight aborted after 12 hr successful landing despite pilot's prolonged hyperthermia.	AMFL Simons Chase Beeding Ruff Yagoda Finkelstein	A-9 S-14 Y-1 Simons with Schanche

(Table Continues)

Biological Experiments in Manned Balloon Flights (Continued)

Flight Desig-nation	Launch Date	Launch Site	Biological Payload	Flight Summary	Investi-gators	Refer-ences
Excelsior I	Nov. 16 1959	White Sands Missile Range, New Mexico	J. W. Kittinger	Parachute jump from open gondola at 76,400 ft; before bailout, the timer lanyard of the stabilization unit was pulled prematurely and the 6-ft canopy and shroud popped out after only 2 sec of free fall instead of 16 sec, promptly fouling around the subject; efforts to retard free spin were unsuccessful and led to unconsciousness; emergency parachute opened automatically at 10,000 ft and permitted safe recovery.	ARDC, WADD Chubb	G-1 K-1
Strato-Lab 4	Nov. 28 1959	Strato Bowl, S. Dakota	M. D. Ross C. B. Moore	To 81,000 ft; successful.	U.S.Navy, ONR Yagoda	R-3 Y-1
Excelsior II	Dec. 11 1959	White Sands Missile Range, New Mexico	J. W. Kittinger	Parachute jump from open gondola at 74,700 ft; "everything worked perfectly."	ARDC, WADD Chubb	K-1
Excelsior III	Aug. 16 1960	White Sands Missile Range, New Mexico	J. W. Kittinger	Parachute jump from 102,800 ft; 6-ft stabilization canopy opened at 96,000 ft; 614-mph peak velocity of fall attained at 90,000 ft; at 17,500 ft or 4 min 38 sec after free fall began, main parachute opened for safe landing; this open-gondola and parachute jump exposed subject to space conditions longer than any other man, without harmful effects; 13 min 45 sec marked the elapsed time from bailout.	ARDC, WADD Chubb	K-1

ANNOTATED BIBLIOGRAPHY

A-1 Anonymous, "Studies planned for new stratosphere flight with helium," National Geographic, LXVII:795-800, June 1935

Construction of the aerostat and nature of the experiments contemplated are outlined and supplemented with illustrations.

A-2 Anonymous, "A report of the second stratosphere expedition," National Geographic, LXVIII:535-536, Oct. 1935

The story of the unforeseen accident, hitherto unknown in the history of ballooning, causing the collapse of the three-million-cubic-foot balloon, Explorer II, on July 12, 1935.

A-3 Anonymous; "Twentieth anniversary of the epoch-making stratosphere flight by Explorer II," National Geographic, CVIII:707, 1955

The flight's value grows with the years. Only one year after this anniversary Strato-Lab I challenged the old accomplishment. Captain Stevens, Commander of the Explorer II, held the retired Army rank of lieutenant colonel at his death in 1949. Captain Anderson, the pilot, became a major general in the Air Force, retiring in 1950.

A-4 Anonymous, "Strato-Lab: then and now," ONR Research Reviews. pp. 15-18, Nov. 1957

Among important questions Strato-Lab flights are helping scientists to answer: Where do primary cosmic rays come from? What changes occur in the stratosphere from one level to another? How bright is the sky when viewed at the outer margin of the atmosphere? How does the human body react to high-altitude flight? Outlined briefly, with future plans of this program, are the accomplishments to date.

A-5 Air Force Missile Development Center, Historical Branch, "The beginnings of research in space biology at the Air Force Missile Development Center, 1946-1952," AD 208018, Holloman AFB, New Mexico, USAF, ARDC, 1958

The first installment toward fulfilling the need for examining the history of Air Force participation in space-biology research. A serious study of the origins of biological projects, their gradual evolution, and their scientific and technical contributions is of considerable value in avoiding old mistakes or duplicating previous effort, and for suggesting new paths of endeavor in the planning and pursuit of the more complex programs required in the immediate future. The V-2 and Aerobee rocket experiments and balloon flights are reviewed, with emphasis upon the biomedical information obtained therefrom. Experiments included fungus spores, fruit flies, mice, hamsters, cats, dogs, and monkeys as subjects. The effect at high speed and altitude of G forces, subgravity, and cosmic radiation were major factors explored. Experience gained in rocket and balloon launching, instrumentation and recovery techniques, and the growing collection of scientific data particularly related to cosmic radiation and subgravity problems marked the practical beginning of Air Force research in space biology. (Abstract identical with abstract a-9.)

A-6 Air Force Missile Development Center, Historical Branch, "History of research in space biology and biodynamics at the Air Force Missile Development Center, 1946-1958," Holloman AFB, New Mexico, USAF, ARDC, 1958

A report designed for filling the needs of a comprehensive history of biodynamics and space biology research at HAFB. It attempts an accurate but not too technical account of actual project research during the period 1946 to 1958, and at the same time seeks to demonstrate how the AMFL and its truly significant achievements have been related to work carried on at other institutions within the same general fields of study.

A-7 Air Force Missile Development Center, Historical Branch, "Major achievements in space biology at the Air Force Missile Development Center, 1953-1957," Holloman AFB, New Mexico, USAF, ARDC, 1958

This historiographical effort was prepared as part of a larger history of aeromedical research at HAFB. Important technological advances, discussed in the initial portion of this study, contributed to outstanding accomplishments in two broad fields of space biology research—cosmic radiation and controlled artificial environments. Scientific and engineering progress in these latter fields is the main theme of this publication, which culminates with a review of the record-making Manhigh II flight.

A-8 Air Force Missile Development Center, Historical Branch, "Contributions of balloon operations to research and development at the Air Force Missile Development Center, 1947-1958," Holloman AFB, New Mexico, 1959

The accomplishments of Holloman's Balloon Branch have contributed significantly to the work of many other units—various missile projects, research in space biology and biodynamics, the exploration of the upper atmosphere, and the development of artificial cabin environments which will be required for manned space flight. In addition, they have materially furthered the entire state of the art of ballooning itself. The contributions of 12 years of balloon operations at this major test, research and development center are carefully documented.

A-9 Air Force Missile Development Center, "Manhigh III USAF manned balloon flight into the stratosphere, as reported by pilot and task scientists," AFMDC-TR-60-16, Holloman AFB, New Mexico, USAF, AMFL, Apr. 1961

This report covers the manned balloon flight, Manhigh III, the third and last of a series of flights into the stratosphere directed by the AMFL. Twelve sections, prepared by the pilot and the task scientists, describe the vehicle and its performance, selection and preparation of prospective pilots, the principal psychological and physiological parameters of the subject before, during, and after the flight, the operation of a sealed environment under space-equivalent conditions, cosmic radiation studies, and related problems such as pilot's nutrition.

B-1 Barr, N. L., Shepp, B. E., Yarczower, M., and Standaert, F. G., "Physiologic responses to stressful stratosphere flights," J. Aviation Med. 30:334-343 (1959)

A study which attempts to evaluate the effects of flight into the stratosphere upon man's physiological system. The results from two such flights, Strato-Lab I and II, to 76,000 and 85,000 ft, respectively, suggest that high-altitude balloon flights produced no physiological reactions which could be detected by presently available techniques of measuring adrenal cortical hormones, blood electrolytes, or nitrogenous end products. However, evidence is presented that the flights did produce pronounced changes in the white-blood-cell count. In addition, the data suggests that these changes were due to psychological rather than physical stress.

B-2 Beal, J. M., "Negative results following exposure of several kinds of seeds to cosmic rays and other radiation at high altitudes," Botanical Gazette 112:533-534 (1951)

Seeds of several species of angiosperms were flown to high altitudes (1947-1948, four flights) with the purpose of determining whether cosmic rays and other radiation might have mutagenic effects that would become evident in their seedlings. With the exception of those seeds sent up on the second flight (none of which germinated), the seeds from the other experimental lots and the control lots showed approximately the same percentage of germination, and the growth and development of seedlings from them were essentially identical. Exposure to cosmic rays and other radiations, notably to the giant atmospheric showers at around 30,000 ft and to heavy nuclei at 100,000 ft altitude, apparently resulted in no visible phenotypic alterations. Thus, under the conditions of these tests, cosmic rays and other radiations seemed ineffective in producing cytogenetic effects on certain seeds and their seedlings.

C-1 Campbell, B., "A biological study of the effects of the heavy particle component of cosmic rays," J. Aviation Med. 25:361-365 (1954)

The rationale is given for the research project to search for and interpret the signs of heavy-particle cosmic-ray effects in mammalian brains. Some successful balloon flights were made, and the animals were recovered in normal health. On subsequent histological examination of these specimens, no evidence of damage was found. However, these flights were not in the latitude with high flux density of the particle component under study. Pending the examination of animals flown at high latitudes, the crucial question of the hazard of heavy cosmic particles cannot be answered.

C-2 Campbell, B., "Research on the biological effects of the heavy primary cosmic rays," HADC-TR-55-8, Holloman AFB, New Mexico, 1955

A theoretical introduction to the problems of investigating the unique features of the heavy particle cosmic radiations. In keeping with principles discussed with relation to the effects of radiation upon the different itssues of the body, the nervous system was chosen for observation. The experimental study reported did not succeed in producing critical material for assessment of the problem. Animals (hamsters and a cat) which have been examined on high-altitude balloon flights (AMFL flights 4, 20, and 30, 1951-1953) have shown no damage, but adequate material from longer, higher, and more northerly flights needs to be studied. The laboratory approach, via cyclotron accelerators, was explored. A sufficiently useful model of heavy-particle cosmic-ray exposure was not found in the available beams of 190 MEV deuterons.

C-3 Chase, H. B., "Cutaneous effects of primary cosmic radiation," J. Aviation Med. 25:388-391, 427 (1954)

The general plan of the investigation of the effects of cosmic-ray heavy primaries on the skin is outlined in this preliminary report. The suggestion is evident from preliminary results that deuterons, with their relatively high specific ionization, are less effective than X-rays in producing greying of hair, and that white hair can occur in the mouse as a result of ionization due to cosmic heavy nuclei. The skin with its hair follicles may then serve as a biological track plate and dosimeter and also as an indicator of a type of tissue damage and of repair following exposure to cosmic-ray heavy primaries. Serial histological sections of large areas of skin taken two months after exposure as yet reveal no effects other than white hairs.

C-4 Chase, H. B., Bliss, J. D. M., Straile, W. E. and Post J. S., "Effects on the skin by cosmic ray heavy particles," HADC-TR-55-2, Holloman AFB, New Mexico, 1955

The effects on skin and the production of white hairs in mice exposed to cosmic-ray heavy primaries on balloon flights (50, 51, and 52 of the 1954 AMFL series) above 90,000 ft are reported. White hairs do occur, frequently in small clusters. Other effects on the skin are difficult to observe, if they occur, and a discussion of the reason for this is presented. The urgent need for ground-level studies with skin exposures through small apertures to stripped carbons and other radiations is emphasized.

C-5 Chase, H. B., and Post, J. S., "Damage and repair in mammalian tissues exposed to cosmic ray heavy nuclei," J. Aviation Med. 27:533-540 (1956)

The authors' summary of AMFL balloon flights in 1954 and 1955 is as follows: A thin-down from a cosmic-ray heavy nucleus can cause a hair follicle to produce a white hair instead of a colored one, the cells supplying pigment granules to the hair being in a cluster of small size and not replaceable. If the ionization track is at certain acute angles relative to the surface of the skin and has sufficient range, several hair follicles can be affected. The capacity of other mammalian cells to be damaged by such tracks of high REL is discussed with relation to the redundancy and replaceability of such cells. Although damage from thin-downs can occur at high altitudes toward polar latitudes, the health hazard from such thin-downs for man and his descendants is perhaps relatively slight compared with the hazard from other ionizing and nonionizing factors to be encountered in stratosphere and space travel. Much additional information, however, is needed concerning the properties in tissue of disintegration stars and of these unique thin-down micro-beams.

C-6 Chase, H. B., Straile, W. E. and Arsenault, C., "Heavy ions and millibeam irradiations on mammalian tissue," Presented at the Aerospace Medical Association Meeting, Chicago, Illinois, Apr. 1961

Greying of mouse hair was described for the 1954 AMFL balloon flights and agreed rather well with H. J. Schaefer's calculations. The 1955 flights were less conclusive. In the summer of 1960, a total of 33 black mice were recovered from three Air Force flights at 130,000-ft altitude from a northern latitude. Monitoring nuclear-track emulsions for each mouse were also available, and charts for all tracks over $Z = 19$ have been made by Brooks Air Force Base personnel. The average number of grey hairs in the prescribed 10 cm^2 in these young mice was 15.3, compared with 5 for the controls. Also of interest was a close correspondence of "streaks" of three to seven white hairs with the long tracks scored at Brooks in the emulsions. These results, with the important added track plate information, confirm the 1954 results.

C-7 Corkhill, J. DeP., "Present cosmic radiation studies," Holloman AFB, New Mexico, AMFL (not dated; 1958 or 1959)

Discusses the progress of the cosmic radiation research conducted and coordinated by the AMFL, HAFB, from Jan. 1 through Aug. 11, 1958. Much of the work now in progress was predicated on suggestions set forth at the January 1958, conference, which was arranged by AMFL and Donner Laboratory, at the University of California to discuss cosmic radiations as they might concern space flights. A brief outline of present studies with the names of the investigators is presented. Balloon flights with biological payloads were scheduled to begin July 1958. In three attempts on the first JIG (animal) flights, none were successful because of balloon

rupture at various altitudes. Flights were halted pending evaluation of the engineering aspects of the balloon failures.

E-1 Eugster, J., "Method for demonstrating the effectiveness of cosmic radiation at high altitudes," J. Aviation Med. 24:222-226 (1953)

During the year 1951, the author with the assistance of the Aeronautical Station in Payerne carried out a series of biological experiments by "hitchhiking" samples with sounding balloons in the altitude range between 28,000 and 30,000 meters. Test objects were 200,000 eggs of Artemia salina (a salt crab), and preserved, excised pieces of human and animal skin to be reimplanted following exposure. Preliminary observations indicate that a direct hit kills an Artemia egg. More valuable information might be expected from further breeding the experimental sample. The main importance of the experiments with skin specimens rests with the fact that tracing of cosmic rays in human tissues has been successfully accomplished, by a method the author proposes to name ichnography, the actual tracking of an elementary particle in the tissue itself. It is concluded that a reliable method has been designed which can contribute not only qualitative results but opens the way for quantitative studies.

E-2 Eugster, J.A., Waeffler, H., and Roost, W., "Effects on living tissues by primary cosmic ray particles," AFOSR-TR-56-19, AD 87528, Dayton, Ohio, Document Service Center, 1956

Report of the authors' experiments to determine the effects of cosmic rays on the living tissues of humans and animals, performed both in Switzerland and on AMFL high-altitude balloon flights. Of 55 experiments reported, 18 involved human tissue; of these, only three gave conclusive results, due to the fact that none of the tests could be carried out at geomagnetic latitudes of more than 55°N. Consequently, there was little exposure to heavy primaries with thin-down hits. Eugster summarizes that "cosmic radiation will not be a great hazard for the human body, hindering to fly in the upper-atmosphere."

E-3 Eugster, J., and Simons, D.G., "Effects of high altitude cosmic radiation on barley seeds," Chapter in "Physics and Medicine of the Atmosphere and Space," New York:Wiley, pp. 182-192, 1960

To study the extent to which cosmic rays are capable of inducing mutations, barley seeds were exposed on a series of AMFL balloon flights at both 42° (flight 39, series A) and above 55° (flights 49 and 50, series C; flight 64, series F and G) geomagnetic latitudes. The evaluated material comprised 280 seeds exposed at altitude between 80,000 and 96,000 ft. From these, 8539 individual plants were grown in five filial generations. Sixteen of the exposed seeds failed to germinate, producing a sterility rate of 7.1 percent. None of these had been scored as hit by heavy primaries. All of the corresponding 97 ground control seeds germinated. The material was divided into four categories for evaluation: (1) ground controls, unexposed seeds and their offspring; (2) flight controls, seeds exposed at high altitude which experienced neither central nor partial hits; (3) seeds experiencing central hits; (4) seeds experiencing partial hits. No statistically significant difference between the average values for ground controls and those for the exposed seeds was observed, with one exception. The X_2 generation of Series A showed a two-fold increase in six of nine characteristics tested.

Eight of twelve characteristics observed showed strongly negative values in the progeny of "central hit" seeds from all series. Color mutations were observed in three seeds suffering central hits from heavy primaries. In all cases, the color changes have remained constant through the third filial generation. Conclusion: the monitoring technique proved quite valuable. Present findings suggest that

primary cosmic radiation has a much stronger mutation effect without destroying the ability of a seed to germinate than the x-radiation used by Gustafsson. The marked increase in the values in the X_2 offspring of Series A flight control seeds may represent a group of recessive mutations producing increased scores which were not balanced by an equal number of mutations producing decreased scores. Only the type of radiation characteristic of galactic cosmic radiation was specifically monitored.

G-1 Geer, R. L. and Rayfield, J. F., "Development and test of a balloon-borne manned vehicle," WADC TR-59-226, Wright-Patterson AFB, Ohio, USAF, ARDC, AML, 1959

Balloon-borne vehicles are well suited for use as a means of lifting parachutists to very high altitudes for test jumping. The design, fabrication, and testing of a vehicle, developed at the WADC for this purpose, are discussed in this report. Included are presentations of novel designs for a pressure-retaining hatch and an energy-absorbing parachute landing device. In general, this vehicle development showed the advantages of a mission-oriented approach to the design of a system. Once the overall mission profile was established, the various requirements and resulting designs seemed to follow naturally, even when the final designs were somewhat unorthodox. Although this balloon gondola was built with a specific mission in mind (bailout tests from altitudes between 60, 000 and 100, 000 ft), it appears suitable for use in other research programs requiring a high altitude manned platform. At present it is being considered as a means of conducting astronomical research at high altitudes for the purpose of establishing criteria for future astronomical systems in both balloon and space vehicles. It is hoped that the work outlined in this report will contribute to any future development of manned balloon systems, especially in the areas of weight-saving and structural design.

G-2 Grosvenor, G., "The Society announces new flight into the stratosphere," National Geographic, LXVII:265-272 (Feb. 1935)

The story of the Explorer I flight, including its successes and failures, is reported from official sources. High-altitude photographs and plans for the subsequent flight are also included.

H-1 Harlow, H. F., Schrier, A. M. and Simons, D. G., "Exposure of primates to cosmic radiation above 90, 000 feet," J. Comp. Physiol. Psychol. 49:195-200 (1956)

Purpose of this investigation was to determine the effects of primary cosmic radiation above 90, 000 ft on the behavior of primates. A group of four Java monkeys was given a series of behavioral tests before and after two of the animals were exposed to altitudes above 90, 000 ft for a total of 62 hours (consecutive balloon flights AMFL 50 and 51, July-August 1954).

Before the high-altitude flights, the animals' performance on the Discontinuous Response Pursuit Apparatus and on planometric color-discrimination problems was recorded. The first postflight test series included retests of discontinuous response pursuit and color-discrimination performance as well as tests on oddity and delayed-response problems and a test of appetite for peanuts and raisins. These tests were repeated beginning approximately four months after the high altitude flights.

The weight, general behavior, and neurological conditions of the animals remained normal after the high altitude flights. The performance of the exposed animals on the different tests showed continued improvement after the flights or was either equal to or better than the control's performance. For these reasons, it was concluded that prolonged exposure to primary cosmic radiation at high altitudes did not produce any general behavioral loss.

H-2 Haymaker, W., "Operationa stratomouse," Military Medicine 119:151-171 (1956)

In this narrative presentation the author lays bare the thinking behind animal experimentation on stratosphere balloon flights. He provides a running account of the personal characteristics of two balloon impresarios, Otto Winzen and David Simons, and the tense moments connected with balloon launching (AMFL flight 67, launched Aug. 22, 1955, from International Falls, Minnesota, and the two related subsequent flights) and balloon pursuit by the experimental investigators involved.

H-3 Hild, W., "Tissue cultures exposed to high altitude" (Abstract), J. Aviation Med. 27:159 (1956)

Cultures of L-strain cells mounted in Rose chambers of 2 ml capacity were sent aloft in pressurized, temperature-controlled gondolas to altitudes of 120,000 to 130,000 ft. Exposure times varied between 8 and 36 hours. Cultures were examined immediately after descent and compared with controls. No differences including the number of dead cells were found.

H-4 Hoffman, R. A., "Radiation hazards of primary cosmic particles," AFMDC-TR-59-32, Holloman AFB, New Mexico, USAF, ARDC, 1959

A summary of the studies conducted concerning radiation hazards of primary cosmic particles. Included as an appendix is a discussion by C. A. Tobias entitled, "Radiation hazards in space flight." The report represents a valuable guide to the flight data and biological results of AMFL flights 40 to 73 and the JIG I flights. It continues in this respect the guide offered by an earlier report of AMFL flights 1 to 39 (see citation S-3).

J-1 Jollos, V., "Mutations observed in Drosophila stocks taken up into the stratosphere," in "The National Geographic Society—U. S. Army Air Corps stratosphere flight of 1935 in the balloon, Explorer II," Contributed Technical Papers, Stratosphere Series, No. 2. Washington, D. C.:National Geographic Society, 1936

The flight of Explorer II offered a unique opportunity to expose four different inbred stocks of Drosophila melanogaster to the influence of cosmic rays within the stratosphere. All specimens flown died before their return to the laboratory. Only ova and larvae produced within the cultures before, during, and perhaps also after the flight were more resistant and survived. Ninety-eight flies (55 males and 43 females) hatched out in these cultures. The breeding tests showed a clear increase, by at least five times, of the mutation rate of the flight group over that of the controls. The low temperature before, during, and after the flight is considered the main cause of the genetic alterations, for, it is argued, due to limited flight exposure it seems hardly possible to attribute this observed effect entirely to cosmic radiations.

K-1 Kittinger, J. W., Jr., "The long, lonely leap," National Geographic, 118:854-873 (Dec. 1960)

A report in narrative style of the author's world-record parachute jump of August 16, 1960, from a balloon-borne open gondola at 102,800 ft altitude. This presentation is replete with colorful photographs and includes accounts of the author's previous preparatory jumps. Some monitored pulse, heart, and respiratory responses during the jump are illustrated; one breath was made to last through virtually the entire unstabilized free fall; the pulse trace shows up to 156 beats a minute (compared with the author's normal pulse of 80). These data and EKG were recorded from instruments in the seat kit. Thirteen minutes and 45 seconds

marked the elapsed time from bail-out to safe landing. It is concluded that the potential of balloons has barely been scratched. It is now known that despite the pulse rate of 156 beats, a healthy man properly equipped can safely expend tremendous energy in space for brief periods. The open-gondola ascent and parachute jump exposed the author to space conditions longer than any other man, without harmful effects. For the future, the author outlines three distinct fields in which manned balloons can play a valuable role in space research. These are: (1) astrophysics research, (2) life-support system, (3) training of space pilots. The author expresses the earnest hope that researchers will not fail to take advantage of the lessons high-altitude balloon flights can teach us before a man is committed to the infinite reaches beyond our familiar world.

L-1 Lebish, I. J., Simons, D. G., Yagoda, H., Janssen, P., and Haymaker, W., "Observations on mice exposed to cosmic radiation in the stratosphere, A longevity and pathological study of 85 mice," Military Medicine 124:835-847 (1959)

A study of possible biological effects of 24-hour exposure to primary cosmic radiation was carried out on 85 mice on AMFL flight 67, launched Aug. 22, 1955, from International Falls, Minnesota. Maximum altitude reached was approximately 109, 000 ft. The animals were at 80, 000 ft or above for approximately 23 hours. Analysis of the balloon trajectory indicates that the mice received collectively a total of 7, 350 thin-down hits by heavy primaries of $Z \geq 6$, of which 59 hits were by members of the calcium-iron group. Control mice on the ground were subjected to the same rigors as the experimental mice. Both the experimental and the control animals were then allowed to live out their life span. Taking into consideration the minor differences exhibited by the experimental and control animals in longevity, incidence of neoplasms, and in reproductivity and aging, there was no definite evidence that a day's exposure to light- and medium-weight primary cosmic particles in the stratosphere had any adverse long-term effect (abstract identical with abstract 1-1).

L-2 Longmore, W. J., "Preparation of control specimens for the 1954 Aero Medical Field Laboratory balloon flights," HADC-TN-55-6, AD 66265, Holloman AFB, New Mexico, ARDC, 1955

The method is presented whereby biological specimens (radish seeds and pregnant and nonpregnant female white mice) can be exposed to variations in environmental conditions similar to those encountered on high-altitude balloon flights. These specimens, which are not exposed to cosmic radiation, can be utilized as controls for evaluating the radiation effects in flown specimens. It is concluded that it is practical to prepare such controls through the use of an environmental chamber.

M-1 Meir, F. C., "Effects of conditions in the stratosphere on spores of fungi," in: "The National Geographic Society—U. S. Army Air Corps stratosphere flight of 1935 in the balloon, Explorer II," Contributed Technical Papers, Stratosphere Series, No. 2. Washington, D. C.:National Geographic Society, 1936

The purpose of this experiment was to determine the effect of conditions in the stratosphere on spores of certain fungi known to be commonly distributed by air currents near the earth's surface. Specimens flown included spores of Brachysporium, Hysterium, Diplodia, Rhizopus, Aspergillus niger, Cladosporium, Helminthosporium sativum. These spores, which were mounted outside the gondola of Explorer II, were carried to an altitude of 72, 395 ft. They were in the stratosphere for some four hours, during which time they were subjected to drying, extreme cold, ozone, strong light rays, and low air pressure. Six of the seven fungi survived, although in the case of one of these (Cladosporium) the percentage

of germination was materially reduced. While the period in the stratosphere was too brief to be conclusive, results of this experiment direct attention to the resistance of the resting stages of some fungi to unfavorable conditions of the upper air, and, consequently, to the possibility of the dissemination of these organisms by means of spores carried by winds at high altitudes.

M-2 Murray, W. D., "A gondola for physiological research in the atmosphere," J. Aviation Med. 25:354-360 (1954)

Under the sponsorship of ARDC, development was instituted of a container specifically designed to carry animals (dogs) weighing up to 20 lb to altitudes between 80,000 and 100,000 ft and to maintain internal conditions at a level to permit flight durations of 36 hours. The NYU College of Engineering, Research Division, carried out this program in collaboration with the AML, WADC. Chamber and ground tests of the container were successful. Of the several flight tests attempted, the first was performed before need for the cooling system was ascertained and was a failure due to overheating, although other components operated satisfactorily. A second flight test, including a cooling system, was unsuccessful due to a balloon failure during ascent. In a third experiment equipment was lost by the tracking aircraft. It is planned that a series of evaluation flights will be performed to perfect the tracking and recovery system. Afterwards, experiments will be undertaken to determine cosmic-radiation effects on animals.

N-1 National Geographic Society, "The National Geographic Society—U. S. Army Air Corps stratosphere flight of 1935 in the balloon, Explorer II," Contributed Technical Papers, Stratosphere Series, No. 2. Washington, D. C.:National Geographic Society, 1936

The 278 pages of this volume combine 29 contributed papers for a complete detailed report of this epoch flight of Nov. 11, 1935, by A. W. Stevens and O. A. Anderson to the record altitude for a manned balloon of 72, 395 ft above sea level.

P-1 Piccard, A., "Ballooning in the stratosphere," National Geographic LXIII:353-384 (Mar. 1933)

Two balloon ascents, May 27, 1931, and Aug. 18, 1932, to a ten-mile altitude presage a new mode of aerial travel. The sources, nature, and results of these two epochal flights are reported in narrative style amplified by numerous illustrations. The first ascent was considered free of dramatic incident, and from a scientific standpoint as being less important than the second ascent, which was of greater scientific importance because of the studies made of cosmic rays and the measurements taken. Moreover, the ascents demonstrated the practical possibilities of the air-tight cabin for future rapid travel through the stratosphere.

P-2 Pipkin, S. B. and Sullivan, W. N., "A search for genetic change in Drosophila melanogaster exposed to cosmic radiation at extreme altitude," Aerospace Med. 30:585-598 (1959)

In all, 10, 761 Drosophilae were exposed as larvae to primary cosmic radiation during the Strato-Lab III balloon flight of July 26-27, 1958, which remained at altitudes from 78, 000 to 82, 000 ft for 16 hours. The control series included 7, 742 individuals. No demonstration of X chromosome breakage in gene mutation at specific chromosome loci was possible, either because of the rarity of thin-down hits or of nuclear collisions or because of lethal effect of the former.

R-1 Ross, M.D. and Lewis, M.L., "To 76,000 feet by Strato-Lab balloon," National Geographic CXI:269-282, 1957

When LCDR Ross and LCDR Lewis were preparing to invade the stratosphere, they found that the detailed reports of the record-breaking National Geographic Society - U.S. Army Air Corps flight of nearly 21 years before were still among the best sources of data on the upper atmosphere. In appreciation and in recognition of the Society's long and active interest in the stratosphere, they have contributed this narrative of their historic flight.

R-2 Ross, M.D., "Balloon astronomy," ONR Research Reviews p. 5, May, 1958

In addition to a brief historical review of the subject, current and future objectives of the long-range Strato-Lab and Stratoscope programs are outlined.

R-3 Ross, M.D., "Flight prospectus, Strato-Lab High 4," Washington, D.C. ONR, 1958

The flight has one clear primary objective—astrophysical research from a balloon. On a noninterference basis, secondary objectives include in-flight telemetering of physiological data from the flight crew and miscellaneous observations of ground and sky as time permits.

R-4 Ross, M.D., "Navy interests in sealed cabins," Prepared for presentation at the Sealed Cabins Session, American Rocket Society, 13th Annual Meeting, New York, November 17-21, 1958, Washington, D.C., ONR, 1958

Two widely divergent crafts (submarines and high altitude vehicles) use sealed cabins, enclosing an artificial environment to harbor personnel. It is argued that improvement of the man-machine operation, whether submarine or high-altitude aircraft, hinges upon precise values for maximum comfort of individuals in such systems. Departures above and below these values determine discomfort and degradation in efficiency. The basic philosophy of design should meet human requirements and conveniences rather than attempt to force man to adapt to undue stress.

R-5 Ross, M.D., and Lewis, M.L., "The Strato-Lab balloon system for high altitude research," J. Aviation Med. 29:375-385, 1958

Strato-Lab was conceived in 1954 to utilize the plastic-balloon potential and to allow experiments which required personnel as observers, as inexpensive servomechanisms for scientific instrumentation or simply as subjects for research. It was initially recognized that three major areas which could benefit from this research tool were: (1) research in aviation medicine, (2) physical measurements (including geophysical and astrophysical), and (3) evaluation of certain military components, techniques, and equipment. Historical developments in ballooning are traced, with specific emphasis given to an account of the authors' record flight in November, 1956, to 72,000 ft. Feasibility of the systems and accomplishments of the project were satisfactorily demonstrated.

R-6 Ross, M.D., "A comparison of artificial environments used in sealed cabins during flights into the stratosphere, "Advances in Astronautical Services," New York: Plenum Press, IV:1959

Under the Navy's Strato-Lab research program, three balloon ascents in cabins have been made. Total internal pressures of about one-half an atmosphere were used for the first two ascents, and the third flight maintained a total cabin pressure roughly equivalent to sea level. Three system changes were made for the third ascent: (1) internal gondola pressure was maintained at approximately one atmosphere, (2) better humidity control was achieved by substituting potassium hydroxide for lithium chloride, lithium hydroxide, and the molecular sieve, and (3) Air Force partial-pressure suits were used as emergency garments only during ascent and descent; while at floating altitude comfort was improved by removing the helmets and gloves. Although the third ascent was aloft for a period of 34.7 hours (compared with 4 hours and 9.5 hours for the previous flights) it was found, from a subjective comparison, that the cumulative effect of the changes resulted in a marked improvement of the comfort and capability of the personnel to carry out assigned tasks. Since three variables were changed, it is impossible to determine the contribution of the individual changes. In each case, however, the trend was to provide personnel with an atmosphere and conditions more closely approaching their natural sea level environment. In the development of future sealed-cabin systems, greater emphasis should be given to maintaining man's natural sea-level environment rather than trying to adapt people to fit engineering conveniences.

R-7 Ross, M.D., "Reactions of a balloon crew in a controlled environment," J. Aviation Med. 30:326-333, 1959

A discussion confined to results of two representative flight-simulation tests (June 29 and Oct. 26, 1956) and two actual flights (Strato-Lab 1, Nov. 8, 1956, and 2, Oct. 18, 1957) of a two-man balloon crew in a spherical sealed cabin gondola with a controlled atmosphere. In all four tests the environmental control system was essentially the same. A five-liter converter provided oxygen; sponges impregnated with lithium chloride removed water vapor from the cabin air; and carbon dioxide was collected with lithium hydroxide crystals. Test results considered herein include only the operation of the environmental control system and the subjective reactions of the flight crew. Several areas of caution are discussed relative to the test findings. It is believed unrealistic, even dangerous, to extrapolate chamber test results directly into firm requirements and specifications for manned orbital vehicles. It is urged that the manned balloon be used to the fullest as a research laboratory and as a space-flight simulator to extend ground-chamber test results into more realistic situations. Human engineers must vigorously attack and solve some of the seemingly minor problems of the system to assure efficient human operation and system compatibility. Pressure suits and associated protective equipment appear to be best suited to the departure and reentry phases of satellite flight. They seem not at all compatible for continuous wear during orbital flight. The major problem will be the hazard of meteor penetration. After a finite probability of explosive decompression is determined, it will then be necessary to consider accepting this as a calculated risk to permit the crew to remove their protective equipment. This is believed to be a very important aspect which must be investigated thoroughly and reviewed objectively before a decision is made. In crew selection, the psychological reaction, "the break-off phenomenon," must be better understood, since it may be an important yardstick. The still-unresolved engineering problems for relatively short-duration flights with a crew of two in a simple sealed cabin, which are being investigated under the Strato-Lab program, emphasize the need for a full coordination of the information and experience in many technical fields and the blending of know-how in submarine and aviation medicine.

S-1 Schwoebel, R.L., "Strato-Lab development," final report No. 1648, Minneapolis, Minnesota:General Mills, Inc., Mechanical Division, Dec. 1956

A tape-reinforced balloon, investigated in the course of this study as a possible heavy-load vehicle, is discussed. The scientific value of the Strato-Lab system hinged on the provision of an environment which did not impede the normal functions of the gondola occupants. Accordingly, a pressurized gondola was chosen to provide an artificial atmosphere. A desiccant system utilizing lithium chloride and lithium hydroxide was developed to provide a partial pressure of carbon dioxide not exceeding 6 mm of Hg and a relative humidity not exceeding 50 percent at a temperature of 50°F. An oxygen supply and gondola pressure-maintenance system was designed to maintain a minimum pressure of 380 mm of Hg and a minimum oxygen partial pressure of 110 mm of Hg. The operating characteristics of this atmosphere maintenance system were evaluated by a series of five chamber tests. The gondola was equipped with instrumentation to indicate and/or record such flight data as altitude, gondola pressure, oxygen and carbon dioxide partial pressure, and the vertical speed of the balloon. Included also was a specially designed multichannel communications link. To determine the characteristic vertical dynamics of the Strato-Lab system in the stratosphere, two radio-controlled balloon flights were conducted. A cargo-type parachute, utilized as an alternate mode of descent, was released at an altitude of 38,500 ft loaded with an equivalent gondola mass. The culminating effort of this development was a personnel flight to a maximum altitude of 76,000 ft. The flight was prematurely terminated by a malfunctioning balloon valve.

S-2 Simons, D. G., "Methods and results of one year of balloon flights with biological specimens," J. Aviation Med. 25:380-387 (1954)

Instrumentation and balloon tracking techniques are described which permitted serial 30-hour flights designed to float at 90,000 ft. Environment-control techniques have been developed which permit the oxygen-consuming equivalent of 60 mice to be flown at 90,000 ft. Living biological specimens (hamsters, black and white mice, fruit flies, and onions) were exposed to primary cosmic radiation on four successfully recovered flights (Nos. 29, 30, 37, and 38) totalling 56-1/2 hours exposure above 85,000 ft north of 55 degrees geomagnetic latitude. One group of specimens (hamsters, black and white mice) was recovered from two successive flights. Primary emphasis was placed on technical developments. The biological data are submitted as a sample of the type of information that may be obtained by use of the methods described.

S-3 Simons, D. G., "Stratosphere balloon techniques for exposing living specimens to primary cosmic ray particles," HADC TR-54-16, AD 75812, Holloman AFB, New Mexico: USAF, AMFL, 1954

Between August 1951 and December 1953, the AMFL initiated 39 numbered balloon flights. The first 24 flights, through March 1953, were launched from HAFB. During the remainder of 1953, four flights were successfully launched and recovered at geomagnetic latitudes of 55 degrees or greater, where specimens were exposed to heavy primary cosmic-ray particles. Significant advances were made in balloon-tracking techniques and in techniques for heating and cooling animal capsules during 30-hour flights in the stratosphere. The document gives a wealth of technical information on HAFB and AMFL flights 1 through 39. This resume is continued in the report H-4.

S-4 Simons, D. G., "Surface temperature of animal capsules floating above 80,000 feet," HADC TR-56-6, Holloman AFB, New Mexico: USAF, AMFL, 1956

Three AMFL flights, numbers 39, 54, and 60, were instrumented with thermistors from which surface temperatures of animal capsules were telemetered during balloon flights in the upper stratosphere. The temperatures observed on one

24-hour flight and two 12-hour flights are presented. The highest daytime temperature recorded was 200°F, and the lowest high altitude night temperature was -40°F.

S-5 Simons, D. G., "Military aspects of observed biological effects of cosmic ray particles," Holloman, AFB, New Mexico:AML, 1956

Summarizes USAF-sponsored cosmic-radiation studies involving exposure of biological specimens to primary cosmic ray particles. Effort concentrated on establishing satisfactory animal-capsule environment control and balloon tracking and recovery techniques. Biological specimens received significant exposure to cosmic-ray primaries at high altitudes on four groups of flights. The first two groups were flown in 1953 from Great Falls, Montana, and Pierre, South Dakota. The third group was launched from Sault Sainte Marie, Michigan, in 1954, and the fourth series was conducted a year later from International Falls, Minnesota.

Two types of experiments were performed. The first employed a test system which reflects indirectly the damage caused by one or more thin-down hits and includes studies of longevity and cancer incidence of exposed mice and a monkey performance study; the second examined the specific damage done by individually identified primary particles and required predetermined tissue to be examined for specific effects. Specific tissue studies included the central nervous system, crystalline lens, integument, developmental studies, and genetic studies.

Published and unpublished experimental findings to date are summarized, and the following conclusions are made: (1) four streaks of tissue damage 200 microns wide (10 times the expected radial spread) apparently due to heavy primaries were observed in mouse skin, (2) comparable streaks of damaged nerve cells have not been observed, (3) preliminary studies indicated a genetic hazard of unknown degree, (4) one monkey experiment indicated no marked indirect hazard from 65 hours exposure at 90, 000 ft, (5) animal experiments have demonstrated no somatic health hazard of military significance following exposure to heavy primaries for 24 hours.

S-6 Simons, D. G., and Parks, D. P., "Improved techniques for exposing animals to primary cosmic ray particles," J. Aviation Med. 27:317-321 (1956)

Experience gained from the 1954 series of flights indicated the need for a number of improvements in capsule design in terms of size, weight, temperature control, electrical equipment, oxygen and carbon dioxide absorber system, instrumentation, tracking, material construction, and balloon size. Reduction of the weight of the AMFL capsule from 165 to 70 lb was achieved by redesign and reduction of the weight of components whenever possible. Emphasis was placed on maximum reliability of each component, and extensive test procedures were established to insure normal functions of all systems. Flying the lighter capsule under a larger balloon with a lighter instrumentation permitted exposure of three groups of biological specimens to heavy cosmic-ray primaries in the five-millibar (120, 000-ft) region.

S-7 Simons, D. G., and Parks, D. P., "Climatization of animal capsules during upper stratosphere balloon flights," Jet Propulsion, pp. 565-568, July 1956

Experiments requiring exposure of animals to primary cosmic radiation at altitudes above 90, 000 ft on 24-hour balloon flights have led to the development of environmental control techniques. Simple methods for supplying oxygen and removing carbon dioxide were developed. Internal capsule temperatures have been maintained at very nearly room temperature on 24-hour flights by providing adequate insulation to use animal heat at night, and by cooling the capsule with a water-can cooler during the daytime. Report includes comparative records of internal capsule temperature during a daylight flight without internal heat source or cooling (flight 61) and during a 24-hour flight with animals (12 guinea pigs) and the thermostatically controlled cooling system (flight 65).

S-8 Simons, D. G., and Steinmetz, C. H., "The 1954 Aeromedical Field Laboratory balloon flights. Physiological and radiobiological aspects," J. Aviation Med. 27:100-110 (1956)

Reviews the nature and biological hazard of primary cosmic radiation and the method of exposing biological specimens to this radiation in a sealed capsule using plastic stratosphere balloons. Information concerning the protocols of various biological experiments and the flights in which the specimens were exposed is presented. The available experimental results are reviewed and discussed in relation to calculations of hit probabilities for the various specimens. The most interesting effect observed is the significant increase in frequency of grey hair on exposed black mice. All tests evaluating impairment of physiological functions have been negative. There have been no results to indicate that cosmic radiation has any biological effect which cannot be explained on the basis of currently available physical descriptions of the radiation at these altitudes. The results indicate that, of the systems tested, primary cosmic radiation may have a relative biological effectiveness of two or greater for the depigmentation effect only.

S-9 Simons, D. G., "Pilot reactions during 'Manhigh II' balloon flight," J. Aviation Med. 29:1-14 (1958)

The Manhigh II balloon flight on Aug. 19 and 20, 1957, that lasted 32 hours and reached an altitude of more than 100,000 ft, was conducted primarily to investigate the human-factor problems of flight under space-equivalent conditions. The conditions encountered were physically equivalent to those in a manned satellite in terms of the near vacuum (10 millibars) ambient pressure, incoming radiation, heat balance and control, and in terms of the emotional reaction toward the overall flight plan. The human factors studies conducted during this flight included (1) evaluation of the sealed-cabin atmosphere and its attendant problems required for any flight into space, (2) reactions to the physical and temporal isolation in a space environment, (3) the effects of heavy primary cosmic radiation on a human subject, and (4) evaluation of the spontaneous activity level and productivity of the pilot subject in terms of the feelings and attitude toward the situation throughout the various phases of flight. This narrative presentation is concluded with cautious emphasis given upon preserving primary, unique advantages of manned flight into new frontiers by resolution of human factors and design engineering problems through closer liaison among specialists. Otherwise, the pilot is at a physiological and psychological disadvantage in realizing his potential for observing previously unsuspected phenomena and fulfilling his ability to project and extend present experiences into future improvements and new areas of investigation.

S-10 Simons, D. G., "Observations in high altitude, sealed-cabin balloon flight," Air University Quarterly Review, 10:65-88 (Summer 1958)

During the past five years the critically important question of the effects of exposure to heavy primary cosmic radiation has been effectively studied, using balloon-borne sealed cabins. The first part of this paper considers the biological effects of heavy cosmic primaries, emphasizing the results to date of exposure of biological materials and animals. The second part reviews flight experiences and observations made on the first two Manhigh flights. Experiments to investigate the biological effects of the unique microbeam produced by heavy cosmic-ray primaries indicate positive results in the graying effect on black mice and in the genetic effects on Neurospora. Concerning the Manhigh II experiment, the monitoring nuclear track plate on the author's left arm bore marks indicating traversals of heavy primary thin-downs of sufficient density to be considered "hits" according to H. J. Schaefer's criteria. Some of the marks on the plate indicated traversals of medium-weight elements in the region between oxygen and silicon, and some traversals of heavy elements on the order of calcium and iron. Five months after the flight the skin under the monitored areas has shown no new growths nor granulomas corresponding to those described by J. A. Eugster. It is concluded that a major source of human-factor information to prepare the way for man to step into space will be the data obtained from very-high-altitude manned balloon flights.

S-11 Simons, D. G., "Observations from the Manhigh II balloon capsules at 30 kilometers," Reprinted from Proc. VIIIth International Astronautical Congress, Barcelona. pp. 388-394, 1957, Springer-Verlag, Wien, 1958

A companion to the paper "Operation Manhigh," presented by Otto C. Winzen (p. 460). Winzen describes the preparation of the capsule and the flight operation as seen from outside the capsule. This paper describes the flight as experienced by the pilot from inside.

S-12 Simons, D. G., "Space medicine - the human body in space," Monograph No. 6, J. of the Franklin Institute Series, Franklin Institute of Pennsylvania: pp. 161-178, 1958

The author's research experiences through his Manhigh II flight are woven into a review of scientific accomplishments and challenges for insuring man's survival in orbital space flight.

S-13 Simons, D. G., and Archibald, F. R., "Selection of a sealed cabin atmosphere," J. Aviation Med. 29:350-357 (1958)

The various physiological variables to be considered in designing a balloon-borne capsule for a 24-hour manned flight are outlined. Design of environmental control equipment should be based on maintaining an atmosphere that provides for no performance decrement, rather than for comfort or survival. A standard liquid oxygen converter can be used for initial exploratory flights. The selection of cabin pressure in relation to possible occurrence of bends in the event of decompression is discussed. All precautions must be observed to prevent ignition of combustible material. The possible use of helium as a replacement for nitrogen is proposed.

S-14 Simons, D. G., "Psychophysiological aspects of Manhigh," Astronautics, pp. 32-33, 63, Feb. 1959

Manhigh flights I, II, and III provided a previously unequaled opportunity to study psychophysiological reactions of individuals to the problems and stresses of living in a space-equivalent situation. Procedures in Manhigh I and II formed a general backdrop for the testing and changes introduced in Manhigh III, viz, training of several candidates for the flight by means of physiological, psychological, and psychiatric evaluations. Three forms of individual evaluation - including an isolation and psychiatric evaluation, and a simulated flight in the Manhigh capsule - were conducted on all Manhigh III candidates of WADC. Manhigh experiments have already suggested strongly that psychophysiological research will play an important part in preparing man for space flight.

S-15 Simons, D. G., "The 'Manhigh' sealed cabin atmosphere," J. Aviation Med. 30:314-325 (1959)

The factors involved in the selection of a sealed cabin atmosphere for space flight are so numerous, and some of the trade-offs so close, that the final decision must be based on the specific needs of the mission concerned. The needs of the Manhigh flights lead to the selection of a cabin total pressure of 300 mm Hg, 60 percent oxygen, 20 percent helium, and 20 percent nitrogen. The factors tending to decrease capsule pressure include a pressure leak, decrease in temperature, absence of oxygen supply, animal metabolism, pressure bleed, and decrease in partial pressure of H_2O or CO_2. Seven ways in which these factors can combine to change the oxygen percentage are related to its changes during the Manhigh II flight. The ambiguities and uncertainties arising from the attempt to interpret the available data would have been greatly reduced if: (1) accuracy of measurements had been increased by a factor of three, (2) the

cumulative volume flow from the oxygen supply had been measured, (3) the partial pressure of H_2O and CO_2 had been measured directly. Instrumentation that permits the astronaut to know at all times what is happening to his atmosphere will be very important in extended space flight.

S-16 Simons, D. G., "Manhigh II," AFMDC-TR-59-28, AD 216892, Holloman AFB, New Mexico, USAF, ARDC, 1959

David G. Simons ascended in the Manhigh II plastic balloon to an altitude above 99 percent of the earth's atmosphere, achieving a world's record for free balloon flight of 101, 516 ft. Here, on his stable platform, the pilot was able to make synoptic observations of his own condition, of the functioning of the artificial world in which he was living, and of various phenomena of high interest to geophysicists. In the present report, this work, as well as the preparation for and the development of the program, are reported by the participants.

Project Manhigh II was specifically undertaken to investigate the human factors of space flight. It sought to discover how man reacts in this hostile environment and at the same time to learn more of the design principles for space capsules and how to study man's reaction therein to permit intelligent planning of future space-flight experiments. This project is presented as a series of explorations on many scientific fronts, with the hope that the information gathered during this flight will make succeeding high-altitude penetrations by man more rewarding scientifically.

S-17 Simons, D. G., "Radiation in space: II. Biological effects," from "Lectures in Aerospace Medicine," USAFSAM, Jan. 1960

Biological effects of space radiations are considered in three categories: planetary (Van Allen) radiation zones, solar cosmic radiation, and galactic cosmic radiation. The absence of any biological experiments exposed directly to either planetary radiation or solar cosmic radiation permits conclusions based only on theoretical considerations. The bullet-like tracks produced by primary cosmic radiation become of concern only above 75, 000 ft. The track effects experienced from this radiation are identified in four stages: physical, physiochemical, chemical, and biological. The effects observed in biological specimens exposed to track producing high energy particles were examined in three nonspecific experiments. Their negative results indicate no serious health hazard is anticipated from 24-hour exposures to galactic cosmic radiations in the vicinity of the earth's orbit. A series of experiments in which individual primary particles were monitored to identify the specific biological effects reveal unique radiobiological phenomena. The occurrence of streaks and clumps of grey hair observed in mice exposed at high altitude correlates with the track-plate-monitored experiment on the pilot of Manhigh II. Lesions observed in guinea-pig brains suggest that central nervous system tissue may be susceptible to the bullet-like radiation pattern of heavy primaries. Observations on black mice exposed to the HILAC beam by Chase and Tobias demonstrate unique cutaneous tissue changes. Positive results on high-altitude exposures of Neurospora material for evaluation of genetic changes confirm the expectation that individual tissues will show characteristic response patterns to track-producing radiation. These positive results warn that the hazard of exposure to galactic cosmic radiation for periods of a week or more in the regions of space well beyond the earth's orbit are undetermined. The total radiation-hazard picture in space looks hopeful, but it is dependent upon the resolution of a number of gaps in our knowledge of the physical exposure present and completion of confirmatory biological experiments in space.

S-18 Simons, D. G., "Biological implications from particular radiation (carbon and heavier)," paper presented Oct. 26, 1960, DAY III at Symposium "Medical and Biological Aspects of the Energies of Space," School of Aviation Medicine, Brooks AFB, Texas

Concerns the radiation effects of primary cosmic particles of carbon and heavier, reviewing what is known and indicating what clearly remains unresolved. The experiments conducted to date have not revealed any biological effect of sufficient seriousness to warrant concern for the health of the astronaut exposed to heavy primary cosmic radiation for a 24-hour period. There are numerous unexplained effects observed in accessible tissue (skin) which prompt the question of whether or not comparable effects may occur in tissues not so readily observed.

S-19 Simons, D. G., "Biological hazard of space radiation," chapter in "Medical Physics," Glasser, O., (ed), Vol. III, p. 64, Chicago, Illinois: Year Book Publishers, 1960

Discusses the nature, source, and distribution of the known forms of radiation in each of three regions of space: galactic, interplanetary, and cislunar, and the biological significance of each region.

S-20 Simons, D. G., DeBusk, A. G., and Hewitt, J. E., "Bioastronautics 1959 primary cosmic radiation research program," paper presented at the Annual Meeting of the Aerospace Medical Association, April 1960, Chicago, Illinois; Brooks AFB, Texas: SAM, 1960

The techniques developed to examine the unique biological track effects produced by the high-energy heavy ions characteristic of primary galactic cosmic radiations are presented. The report includes the flight experiments conducted during 1959 and reviews related laboratory experiments. Nuclear emulsion track plates (NTB-3) were used to monitor primary cosmic particles of $Z \geq 6$ traversing biological materials exposed for 13 hours at 127,000 ft on a balloon flight, and above the atmosphere for 4-1/2 minutes on a rocket flight. The materials exposed included Neurospora crassa, HeLa cells, E. coli, rat ganglion cells, barley seeds, and flower beetle eggs. Correlation of positive results between disks impregnated with Neurospora crassa N-51 conidia spores and the corresponding track plates emphasize the importance of track-plate monitoring in the interpretation of results, and the value of combined quantitative and qualitative methods of assessing the biological effects. (Abstract identical with abstract s-3.)

S-21 Simons, D. G., and Hewitt, J. E., "Review of biological effects of galactic cosmic radiation," paper presented at the 32nd Annual Meeting of the Aerospace Medical Association, Chicago, Illinois, Apr. 25, 1961

A discussion of galactic cosmic radiation, although some aspects of solar cosmic rays are mentioned for comparison, since the two overlap in composition and energy. The authors conclude: (1) the high correlation between the heavy primary tracks observed in monitoring track plates and the position of loci of greying in black mice reported by H. B. Chase suggests that heavy particles of higher energy and lower total specific ionization than previously expected are responsible, (2) these results emphasize the need for developing techniques which are practical for monitoring biological specimens but which identify more accurately both the charge and energy of galactic primary particles, (3) comparison of heavy primary exposures observed in rocket, balloon, and satellite flights clearly indicates that for this type of experiment balloon flights at a minimum altitude of 140,000 ft provide the most desirable type of exposure.

S-22 Simons, D. G., Hewitt, J. E., and Marbach, J. R., "School of Aerospace Medicine participation in the Bemidji 1960 cosmic radiation balloon flight series," draft copy, School of Aerospace Medicine, 1961

A series of high-altitude space-radiation balloon flights was sponsored jointly by the ARDC and the SAM. The flights were launched from Bemidji, Minnesota

(57.5° N geomagnetic). A temperature-controlled capsule with oxygen supply carried nine biological experiments. All flights were successful. Some biological experiments suffered from high experimental noise level. The graying effect of black mice was the only clearly established effect of cosmic radiation.

S-23 Stapp, J. P., "The first space man" Astronautics 2:30-31, 82-83 (1957)

A step-by-step report by the flight's flight surgeon of the 32-hour balloon flight of Major David G. Simons to an altitude of 100,000 ft.

S-24 Steinmetz, C. H., "Experimental material flown on Aero Medical Field Laboratory balloon flights 46 through 71," HADC-TN-56-2, AD 113031, Holloman AFB, New Mexico: USAF, ARDC, 1956

This note, designed to serve as a reference, presents a brief description of the nature of the experiments and a record of the quality and type of material flown on each of 16 flights conducted during the period from July 14, 1954, through Sept. 20, 1955. Biological experiments involving mammalian species were study of the integument, histological studies, study of the eye, evaluation of exposed primates, leukemia study, and longevity study. Other biological experiments included study of effects on development, genetic studies, and miscellaneous studies (by Krebs and Eugster). Physical experiments utilized nuclear track plates to record cosmic-ray particles and experimental altimeters. Data are presented in tabular form. Some statements regarding the general status and significance of the various experiments are made, along with references to more extensive analyses presented elsewhere. This publication is a valuable guide to biological results of flights 46 through 71.

S-25 Steinmetz, C. H., "Techniques used for monitoring biological specimens on the 1954 and 1955 Aero Medical Field Laboratory balloon flights," HADC-TN-57-1, AD 123731, Holloman AFB, Mexico: USAF ARDC, 1957

Research is being conducted into the human factors of space flight regarding radiation hazards of primary cosmic particles. Animal specimens were flown in sealed capsules for 24 hours at altitudes greater than 90,000 ft by means of balloons. Several types of helmets were monitored for cosmic-ray-particle hits, in addition to mouse skins, Artemia (brine shrimp) eggs, and tissue cultures.

S-26 Stevens, A. W., "Exploring the stratosphere," National Geographic LXVI:397-434 (Oct. 1934)

The Explorer I stratosphere expedition is described in detail and is amplified by numerous photographs. A rip occurred in the aerostat at altitude, and the three-man crew escaped by means of their personal parachutes. Data were salvaged from several of the many scientific experiments. Every item of scientific equipment and instrumentation attached to the gondola worked exactly as planned. It is concluded that the ascent successfully solved the problems of living and working efficiently in the stratosphere.

S-27 Stevens, A. W., "The scientific results of the world-record stratosphere flight," National Geographic LXIX:693-712 (1936)

The flight added a number of new facts to the store of knowledge. Cosmic rays measurable by their ionization effects, coming in from the vertical direction, increase in number from sea level to a certain altitude (57,000 ft during the flight of Explorer II), then decrease in number as the measuring instrument rises. At 72,395 ft measurable cosmic rays coming from the horizontal are as numerous as those from the vertical.

The first records were obtained of bursts of energy from atom disruption by cosmic rays up to 72, 395 ft. The flight resulted in obtaining the first track ever made directly in the emulsion of a photographic plate by a cosmic ray of the alpha-particle type with the enormous energy of 100 million electron volts. The first values were obtained by means of laboratory-size spectrographs of sun and sky spectra up to 72, 395 ft. A photograph made from the stratosphere was the first to show the curved top of the troposphere (marked by the dust which extends up to that altitude), and it also showed the curvature of the earth. The first values were obtained for electrical conductivity of the air from 30, 000 to 72, 395 ft above sea level. The first samples of air were secured from an altitude above 70, 000 ft, showing practically no change in the ratio of nitrogen to oxygen. The first knowledge was obtained that living spores float in the atmosphere above 36, 000 ft. The first demonstration was made that spores will withstand physical conditions in the stratosphere up to 72, 395 ft, for at least four hours. The first natural-color photographs were taken of the sky at high altitudes in the stratosphere. The first records were obtained showing brightness of the sky at 72, 395 ft. The first record was made of the brightness of the sun at 72, 395 ft (20 percent greater than when viewed from the earth). Vertical photographs of the earth were made from a higher altitude than ever before (72, 395 ft above sea level). The first radio signals were sent to earth stations from a station as high as 13. 71 miles above the earth.

W-1 Winzen Research, Inc., "Flight series in Minnesota, summer 1955, " Final Report, Vol. II, No. 1163-R, Minneapolis, Minnesota:Winzen Research, Inc., not dated

Presents the time-pressure data and horizontal trajectories for each of the flights conducted in Minnesota during the summer of 1955 (July 18 - Sept 20) for the USAF AMFL. Included is a discussion of the procedure used in evaluating the measurements and a summary of the performance of the plastic balloons and factors related to this performance. Volume I of this final report describes the telemetering equipment, ballast controls, flight operations, and balloon construction. The purpose of this flight series was to expose tissue and living animals to cosmic rays at high altitudes. Most of the flights were above 99 percent of the earth's atmosphere, and consequently the absorption effects of the earth's atmosphere on cosmic rays were largely absent.

W-2 Winzen Research, Inc., ONR-WRI project Strato-Lab, "The Strato-Lab gondola - a space laboratory, " Minneapolis, Minnesota, 1955, revised 1956

A picture story of the Strato-Lab gondola as designed and built by Winzen Research, Inc. On Nov. 14, 1955, the completed gondola was delivered to the Navy.

W-3 Winzen, O. C., "Bridgehead in space, " Interavia XII:1040-1041 (1957)

O. C. Winzen, as author and director of the research, design, construction, testing, and flight operations for project Manhigh, renders an account of the system developed for the Manhigh II flight, presents a brief protocol of the flight, and earmarks the flight's historic achievements.

W-4 Winzen, O. C., "Operation Manhigh II, " Technical Publication 7C, Twelfth Annual Meeting ARS, New York, Minneapolis, Minnesota:Winzen Research, Inc., Dec. 1957

Presents a general description of the historic balloon flight, and more particularly the part for which Winzen Research, Inc., was responsible - the design, construction, and testing of the balloon-gondola system as well as the flight operation itself.

W-5 Winzen, O. C., "The 3 manned stratosphere balloon ascents of 1957, " Preprint No. 833, Presented at the 26th Annual Meeting, Jan. 27-30, 1958, New York:Institute of the Aeronautical Services

The three flights in 1957 (Manhigh I and II and Strato-Lab II), during what may well be remembered as the breakthrough year, not only of spaceflight, but also of the plastic stratosphere balloon, have resulted in the following achievements: (1) the reliability of the large plastic balloon in manned flight operations at new record altitudes, (2) the reliability of manned sealed cabins in conducting high-altitude research operation, (3) demonstrated ability of a one-man capsule to operate under space-equivalent conditions in a day/night operation, as a step toward a manned satellite cabin, (4) physiological and psychological data on the human factors of space flight, also including cosmic-ray exposure tests, (5) test of a new oxygen-helium-nitrogen atmosphere under laboratory conditions, (6) data on the use of telescopes in manned balloon systems, (7) demonstration of airborne geophysical research laboratory, with divided duties of pilot and observer, (8) demonstration of manned-balloon station as aerial weather observation post, with capability of limited navigation utilizing wind currents, (9) observations on pilot visibility and space acclimatization, (10) meterological observations of phenomena not previously known, (11) data on performance of the partial-pressure suit in a new application requiring mobility of the pilot, (12) demonstration of usefulness of manned-balloon stations as a stepping stone in the study of manned space flight, (13) demonstration of reliability in the preparation, launch, communication, tracking, and recovery of a total of three successful flights. The author outlines future work for astronomers, meteorologists, geophysicists, radiation physicists, cosmic-ray physicists, and soon-to-evolve new profession of "space surgeons."

W-6 Winzen, O. C., "The Manhigh II balloon operation," Proceedings of the VIIIth International Astronautical Congress, Barcelona, 1957. Springer-Verlag, Wien, 1958

The roles and responsibilities assumed by Winzen Research, Inc., in the design and construction of the balloon and gondola, as well as the flight operation itself, are the purpose of this presentation.

W-7 Winzen Research, Inc., "Strato-Lab High 1," postflight report of system development, No. 1248-R, Minneapolis, Minnesota: Winzen Research, Inc., 1959

In 1954, through ONR, an advisory panel was formed and a series of proposals formulated which ultimately resulted in the Strato-Lab flight of Nov. 8, 1956, in which LCDR Malcom Ross and LCDR Lee Lewis reached an altitude of 76,000 ft. This report has been prepared as a supplement to the other information already made available as a result of this flight. The Strato-Lab gondola system was delivered on Nov. 30, 1955, to ONR and subsequently to General Mills, Inc., who were chosen to conduct the initial manned flight utilizing a 128-ft tailored tapeless balloon as the aerostat. The gondola was subjected to several flight-qualification tests, and the instrumentation and suspension systems were modified to incorporate changes desired by the group responsible for conduct of the flight operation. Unfortunate balloon failure during the flight resulted in the loss of almost all the internal equipment, which was used as ballast to slow the rate of descent.

W-8 Winzen Research, Inc., "Strato-Lab High 3," postflight report No. 1246-R. Minneapolis, Minnesota: Winzen Research, Inc., 1959

The third in a continuing series of manned stratospheric balloon ascents conducted under the Navy's "Project Strato-Lab." Its primary objective was to test the balloon-gondola system during day and night conditions in the stratosphere, as well as the feasibility of using it as a relatively stable platform for balloon-borne telescopic equipment for making observations of heavenly bodies.

The flight covered several significant achievements: for the first time man penetrated the atmosphere in a sealed cabin which contained its own complete, artificial atmosphere which maintained essentially a sea-level environment throughout the entire flight; a new endurance record was set (34 hours, 40 minutes); the two-man

crew (Ross and Lewis) transmitted the first live television pictures in history to be beamed to earth from the inner fringe of space; the complete flight system was the heaviest gross load on record (5, 500 lb) ever borne aloft by plastic balloon.

Details of this report cover the historical design and engineering features of the complete system, including the aerostat, its suspension and parachute features, and the gondola and its associated equipment. Of considerable interest is the information concerning the sealed-cabin ecology, both from engineering and aeromedical aspects. Scope of the report covers the essentials of the entire Strato-Lab High 3 operation, from preflight planning and preparations through launch, flight and landing, to an evaluation of the operation, plus a review of its scientific objectives and the results of some of their associated experiments. Included is a verbatim account of the flight itself by the pilot, CDR Ross.

It should be concluded that this was one of the most successful manned balloon research flights in history. Although the scientific objectives were not completely fulfilled, the ratio of successful research investigations, experiments, and empirical determinations was gratifying in comparison with the failures experienced. Inasmuch as the primary purpose of this flight was to obtain design criteria and performance data of the system for future flights, it must be concluded that the primary objective was completely fulfilled.

W-9 Winzen Research, Inc., "Manhigh I flown by J. W. Kittinger, Captain, USAF," AFMDC-TR-59-24, AD 215867, Holloman AFB, New Mexico:USAF, ARDC, AMFL, 1959

Operation Manhigh I was the first of a series of manned balloon probes into the upper atmosphere, as a preliminary investigation to the Man in Space program. The structure and instrumentation of the capsule and aerostat are described, and the collected data are plotted and analyzed. The following conclusions were formed as a result of this flight: (1) the flight-operation procedures were adequate; launching was accomplished without difficulty, and operations direction was able to cope with unusual and unforeseen development, (2) balloon behavior was as anticipated, (3) flight controls were adequate; command of the balloon was accomplished as desired, (4) the capsule proved capable in most respects of fulfilling its design requirements, (5) a human error in connecting the automatic oxygen control valve resulted in early termination of the flight, (6) the telemetering and communications system functioned as intended; however, a mechanical malfunction resulted in loss of voice communications from the aerostat early in the flight; the emergency provisions were capable of handling an extended flight, (7) the temperature-measuring equipment did not function as intended; analysis of the troubles indicated that the principles on which the instrument operates are valid, but improvement in detail is required; the temperature data gathered on the flight are not accurate enough to allow computation of a geometric altitude to within 750 ft, (8) on the basis of the temperature sounding of the weather bureau at St. Cloud, a maximum altitude in excess of 95, 500 ft can be assumed for this flight; other instrumentation and equipment operated in a satisfactory manner.

W-10 Winzen Research, Inc., "Strato-Lab High 2," postflight report No. 1266-R, Minneapolis, Minnesota:Winzen Research, Inc., 1961

This was the second in a series of manned balloon flights using a sealed-cabin system for the purpose of conducting basic physical and medical research in the stratosphere. This program, sponsored by ONR, is a portion of the U. S. Navy's overall program for upper-atmosphere research. The objectives of this flight were: (1) to detect solar gamma radiation, (2) to study the radiative heat-transfer characteristics of the atmosphere, (3) to study the constituents of the atmosphere at relatively high altitudes, and (4) to study the physiological and psychological reactions of human beings to the stresses and environment of the near-space conditions achieved during the flight.

Ascent date Oct. 18, 1957; maximum altitude 86, 000 ft; duration 9 hours 28 minutes; flight crew M. D. Ross and M. L. Lewis.

This flight gave added evidence of the value and flexibility of the piloted plastic balloon gondola system for use in the furtherance of scientific research at altitudes above most of the earth's atmosphere. In the process of accomplishing its primary flight objectives, this flight also established an unofficial world altitude record for a two-man flight.

Y-1 Yagoda, H., "Cosmic-ray monitoring of the manned Strato-Lab balloon flights," AFCRL-TN-60-640, GRD Research Notes No. 43, Bedford, Massachusetts, USAF, Research Division, Geophysics Research Directorate, Sept. 1960

New observations were made on emulsion blocks and skin monitors during Strato-Lab flights III and IV, and from this information a reevaluation of the results of the Manhigh II flight is presented. A method for monitoring pilots for heavy primary hits on hair and skin structures utilizing nuclear emulsions placed in direct contact with the flat portions of the arms is described. Tracks of heavy primary traversals are plotted, and heavy primary thin-down hits on the Strato-Lab IV and Manhigh II flights are compared and tabulated. The intensity of thin-down hits was found to be not only dependent on altitude and geomagnetic latitude of the exposure, but also markedly dependent on exposure time with the solar sunspot cycle. A seven-fold reduction in thin-down intensity is indicated at the top of the atmosphere during periods of maximum sunspot activity; thus, this natural amelioration of the cosmic-ray hazard should be considered in planning for manned exploration of the moon and planets.

CHAPTER III

BIOLOGICAL AND BIOMEDICAL EXPERIMENTS ON ROCKETS, MISSILES, AND SATELLITES

INTRODUCTION

United States

Numerous instances of proposals and attempts to use rocket power to propel man in flight are cited in the literature. An outstanding example for such a plan is perhaps the following:

> What we would now loosely call 'high altitude' research was carried on in a biological vein by Claude Ruggieri. He is reported to have sent mice and rats aloft in rockets during the 1830's, and he developed a large rocket to accommodate a ram or a small human being. A test, planned for Paris, aborted when police prevented Ruggieri's volunteer passenger, Wilfred de Fonvielle, from taking part. It was probably just as well. Although there was provision for descent by parachute, it would not likely have worked. This was perhaps the first attempt at rocket transportation. . . *

Biological experiments on rockets were started on a more realistic basis shortly after the end of World War II using piggyback rides on captured V-2 rockets at White Sands, New Mexico. Harvard biologists, in cooperation with scientists from the U. S. Naval Research Laboratory, in 1946 and 1947, recovered seeds and fruit flies after flights up to 160 km altitude. In 1948, this group was joined by scientists led by Dr. J. P. Henry, and during the next few years launched successful flights with mice and monkeys as passengers. Besides their interest in the effects of radiation, these investigators made valuable observations on the behavior of animals in the absence of gravitational forces. As the supply of V-2 rockets diminished without replacement, biological experiments on rockets came to a halt in the United States in 1952.

An inactive period of about six years followed, during which no biological experiments on rockets were performed in the United States. Experimentation was resumed on a "piggyback" and "noninterference basis" on military rockets in 1958. The first experiments during this year, in which mice and monkeys were carried with ballistic-missile shots, were only partially successful. The ballistic rocket experiment with monkeys Able and Baker on May 28, 1959, was a complete success, and at the end of 1960 it still held the ballistic flight record for primates in terms of altitude (290 miles) and safe recovery. During the following year, 1960, three events are noteworthy: (1) the successful recovery of biological material from a shot to great altitude (1200 miles) in a NERV capsule, (2) the recovery of three mice after travel over a 5, 000-mile range, and (3) two successful recoveries of satellites carrying biological material. The lack of booster capability and of vehicles assigned exclusively to biological experimentation limits the United States' biospace flight programs at present.

U. S. S. R.

Somewhat later than in the United States - between 1949 and 1952 - systematic, uninterrupted efforts of biological space experimentation were started in the USSR. These efforts led in orderly succession to the manned orbital flights in 1961. The first period, divided by USSR scientists into different stages, covers vertical shots to altitudes up to 280 miles with dogs as nearly exclusive passengers. The main object of these shots, which extended to the year 1960, seems to have been survival at altitude and safe recovery by ejection and parachute systems.

*C. C. Adams, "Space Flight," New York: McGraw Hill, 1958.

In November 1957, only one month after the historic satellite, Sputnik I, the dog Laika blazed a trail leading during the years 1960 and 1961 to a man-carrying spaceship-satellite. This ship was tested in five flights, of which three were successful. The evaluation of the great amount and variety of biological material on these flights must have convinced USSR scientists that manned orbital flight was possible and could be sustained over at least 24 hours. The flights of Gagarin and Titov represent the culmination of the USSR program and a milestone in the history of manned space flight.

TABULAR CHRONOLOGY

Biological Experiments in Rockets, Missiles, and Satellites - U. S. A.

Flight Vehicle	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
			A. V-2 Rockets			
V-2 Rocket No. 7	Jul. 9 1946	White Sands Proving Ground, Las Cruces, New Mexico	Specially developed strains of seeds	To 134-km altitude; samples not recovered.	NRL Harvard Univ.	n-7
8	Jul. 19 1946	White Sands Proving Ground, Las Cruces, New Mexico	Specially developed strains of seeds	To 6-km altitude; samples not recovered.	NRL Harvard Univ.	n-7
9	Jul. 30 1946	White Sands Proving Ground, Las Cruces, New Mexico	Ordinary corn seeds	To 161-km altitude; seeds recovered.	NRL Harvard Univ.	n-7
12	Oct. 10 1946	White Sands Proving Ground, Las Cruces, New Mexico	Rye seeds	To 174-km altitude; seeds recovered.	NRL Harvard Univ.	Newell (1953)
17	Dec. 17 1946	White Sands Proving Ground, Las Cruces, New Mexico	Fungus spores	To 183-km altitude; the spores were not recovered.	NIH	f-3 Newell (1953)
20	Feb. 20 1947	White Sands Proving Ground, Las Cruces, New Mexico	Fruit flies	To 109-km altitude; flies recovered alive.	NRL Harvard Univ.	n-8 Newell (1953)
21	Mar. 7 1947	White Sands Proving Ground, Las Cruces, New Mexico	Rye seeds, corn seeds, fruit flies	To 160-km altitude.	NRL Harvard Univ.	n-8 Newell (1953)
29	Jul. 10 1947	White Sands Proving Ground, Las Cruces, New Mexico	Rye seeds, corn seeds, fruit flies	To 16-km altitude.	NRL Harvard Univ. U. S. Army	n-8

(Table Continues)

Biological Experiments in Rockets, Missiles, and Satellites - U. S. A. (Continued)

Flight Vehicle	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
37 "Blossom No. 3"	Jun. 11 1948	White Sands Proving Ground, Las Cruces, New Mexico	Anesthetized monkey - Project "Albert I"	To 62-km altitude; parachute failed and animal died on impact.	AML, WADC Henry, et al.	a-9 a-10 b-2 h-1 s-2 Mallan
44	Nov. 18 1948	White Sands Proving Ground, Las Cruces, New Mexico	Cotton seeds	To 145-km altitude; seeds were successfully recovered.	Harvard Univ Stroman Lewis	s-6 Newell (1953)
50	Apr. 11 1949	White Sands Proving Ground, Las Cruces, New Mexico	Unknown	To 86-km altitude.	Unknown	Newell (1953)
47 "Blossom No. 4B"	Jun. 14 1949	White Sands Proving Ground, Las Cruces, New Mexico	Anesthetized monkey. Project "Albert II"	To 134-km altitude; parachute failed, animal died on impact.	Henry, et al.	a-9 a-10 b-2 h-1 s-2
32 "Blossom No. 4C"	Sep. 16 1949	White Sands Proving Ground, Las Cruces, New Mexico	Monkey	To 35,000 ft; rocket exploded in mid-air, killing animal.	Henry, et al.	a-10 b-2 Newell (1953)
31	Dec. 8 1949	White Sands Proving Ground, Las Cruces, New Mexico	Monkey	Successful flight; EKG and respiration were reliably telemetered throughout essentially all of the flight.	Henry, et al.	h-1 Simons with Schanche
51	Oct. 31 1950	White Sands Proving Ground, Las Cruces, New Mexico	Mouse	To 136-km altitude; mouse not recovered alive. Pictures of behavior in weightless state.	Henry, et al.	a-10 b-2 h-1

(Table Continues)

B. Aerobee Rockets

Aerobee Rocket No.	Launch Date	Launch Site	Biological Payload	Flight Summary	Investi-gators	Refer-ences
USAF-12	Apr. 18 1951	White Sands Proving Ground, Las Cruces, New Mexico	Anesthetized monkey, several mice	To 61-km altitude; animals not recovered from impact due to parachute failure.	AML, WADC Henry, et al.	a-9 b-2 h-1 h-2 Mallan Newell (1953)
USAF-19	Sep. 20 1951	White Sands Proving Ground, Las Cruces, New Mexico	Anesthetized monkey, 11 mice	The long-awaited breakthrough in parachute recovery was successfully accomplished; to 71-km altitude; all animals recovered alive; monkey died 2 hr after impact; the mice became the first known living creatures to survive actual space-flight conditions.	AML, WADC, Henry, et al.	a-9 b-2 h-1 h-2 Mallan Newell (1953)
USAF-26	May 21 1952	White Sands Proving Ground, Las Cruces, New Mexico	2 anesthetized monkeys, Pat and Mike; 2 mice	To 62-km altitude; animals successfully recovered; Pat and Mike became the first primates to survive actual space-flight conditions.	AML, WADC Henry, et al.	a-9 b-2 h-1 h-2 Mallan Newell (1953)
C. Project MIA						
Thor IRBM and Aerojet 1040 liquid propellent rocket	Apr. 23 1958	Cape Canaveral, Florida	Mouse	Nose cone not recovered.	Van der Wal Young	b-2 g-3 v-1 v-2
Thor IRBM and Aerojet 1040 liquid propellent rocket	Jul. 9 1958	Cape Canaveral, Florida	Mouse - Laska	To 1400-mile altitude; recovered safely.	Van der Wal Young	b-2 g-3 v-1 v-2

(Table Continues)

Biological Experiments in Rockets, Missiles and Satellites - U. S. A (Continued)

C. Project MIA (Continued)

Vehicle	Launch Date	Launch Site	Biological Payload	Flight Summary	Investi-gators	Refer-ences
Thor IRBM and Aerojet 1040 liquid propellent rocket	Jul. 23 1958	Cape Canaveral, Florida	Mouse - Benji	To 1400-mile altitude; recovered safely.	Van der Wal Young	b-2 g-3 v-1 v-2
D. Army-Navy Bio-Flights 1 and 2						
Bio-Flight No. 1 Nose Cone, launched by U. S. Army Jupiter IRBM AM-13	Dec. 13 1958	Cape Canaveral, Florida AFMTC	Unanesthetized squirrel monkey, Old Reliable; Neurospora	To 290 miles apogee, 1300 miles distance; flight successful, although nose cone not re-covered.	ABMA USAM-RDC USN SAM DeBusk	b-2 g-2 g-3 g-4 h-7 k-3 s-1 w-1 y-4
Bio-Flight No. 2 (2A and 2B) Nose Cone, launched by U. S. Army Jupiter IRBM AM-18	May 28 1959	Cape Canaveral, Florida	Monkeys - Able & Baker; Neurospora; samples of human blood; <u>E. coli</u>; onions; mustard and corn seeds; Drosophila pupae; yeast; sea urchin eggs and sperm	To 300 miles apogee - 1500 miles distance; both animals recovered safely; all other experiments re-covered by the U. S. S. Kiowa.	ABMA USAM-RDC USN SAM F. S. U. DeBusk Emory Univ. Portella U. S. Army Medical Lab. Young and Johnson Brook-haven National Lab.	b-2 c-1 g-2 g-3 g-4 h-7 k-3 l-1 s-1 y-2 y-4 y-5

(Table Continues)

E. Discoverer III Flight

Flight Vehicle	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
Discoverer III 1020 - Mark I Biomedical recovery capsule	Jun. 4 1959	Vandenberg AFB, Calif.	4 black C-57 mice	Technical problems prevented successful achievement of orbital velocity, resulting in a prolonged ballistic trajectory and premature re-entry down range.	USAF SAM AFBMD	d-4 g-3 n-2

F. Jupiter AM#23 Flight

Flight Vehicle	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
Jupiter AM - 23	Sep. 16 1959	Cape Canaveral, Florida	Neurospora; human blood sample; E. coli; onions and mustard seeds; Drosophila pupae; sea urchin eggs and sperm; algae cells; tissue culture of human and frog skin; 2 frogs; 12 C-57 pregnant black mice	Unsuccessful missile - destroyed by range safety officer just after launching; experiments not concluded.	NASA AMRL Johnson Metz DeBusk Portella Krebs Young	k-3 y-3 y-4

G. "Little Joe" Flights - Project Hermes

Flight Vehicle	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
"Little Joe" No. 3 Project Mercury Test Flight; NASA Capsule; (ASTRO 59-4)	Dec. 4 1959	Wallops Island Missile Test Center	Monkey Sam Neurospora crassa N-51; flower beetle eggs; E. coli; 10 cultures HeLa strain cancer cells; embryonic rat dorsal root ganglion cells; Neurospora ascospores; barley seeds	To 280,000 ft; flight was successful; capsule recovered.	USAF SAM DeBusk Shrode Davis Katzberg Pomerat Stone Eugster	g-3 g-5 s-3
"Little Joe" No. 4	Jan. 21 1960	Wallops Island Missile Test Center	Monkey Miss Sam	To 49,000 ft; flight was successful; nose cone recovered.	NASA DeBusk	g-3 g-5

(Table Continues)

H. Nuclear Emulsion Recovery Vehicle No. 1 Flight

Flight Vehicle	Launch Date	Launch Site	Biological Payload	Flight Summary	Investigators	References
Ryan Aerolab D-8 Rocket and GE NERV #1 Capsule	Sep. 19 1960	Pt. Arguello, Calif.	Neurospora	To 1200 nautical miles altitude - 1600 miles impact distance; nose cone successfully recovered.	NASA DeBusk	a-5 d-2 k-2
I. Atlas Missile Flights						
Atlas-boosted RVX-2A Re-entry Vehicle	Oct. 13 1960	Cape Canaveral, Florida	3 C-57 black mice-Sally, Amy and Moe; human skin	Nose cone safely recovered from 650-mile altitude - 5000 mile range.	USAF SAM Clamann AF Special Weapons Center	a-6 c-3 g-3 k-4
Atlas	Oct. 26 1960	Cape Canaveral, Florida	The experimental design was similar to that of Discoverer XVII and XVIII	Flight was a failure.	USAF SAM	No report
J. Discoverer XVII and XVIII Flights						
Discoverer XVII, launched by AF Thor Rocket	Nov. 12 1960	Vandenberg AFB, Calif.	Conjunctival and synovial human cell cultures; bacterial spores of Clostridium sporogenes; algae; human gamma globulin; rabbit antiserum	To 616 miles apogee; 116 miles perigee; capsule recovered safely from 31st orbit in air catch by C-119 aircraft.	USAF SAM NASA Crawford Pizzuto Logie Dexter Kohr Davis Roberts Katzberg Phillips Flume	c-4 c-5 d-1 f-2 k-1 k-4 n-3 p-2
Discoverer XVIII, launched by AF THOR Rocket	Dec. 7 1960	Vandenberg, AFB, Calif.	Neurospora conidia; nerve tissue; algae; human bone marrow; eyelid tissue; gamma globulin; cancer cells.	To 459 miles apogee; 154 miles perigee; capsule recovered from 48th orbit in successful air catch by C-119 aircraft.	USAF SAM NASA Crawford, et al; DeBusk	a-8 c-4 c-5 d-1 d-3 f-2 k-1 k-4 n-5 p-2

(Table Continues)

Biological and Biomedical Experiments in Rockets and Satellites - USSR

A. Vertical Rockets

Experimental Stage and No. of Flights	Launch Dates	Biological Payload	Flight Summaries	Investi-gators	Refer-ences
First stage; 6 rocket flights	"1949-1952" (first rocket launched in 1951)	Pair of dogs on each flight-total of 9 dogs (3 flown twice) in hermetically sealed cabins; the 2 dogs were attached separately to special frames	To 100.8 km at velocities up to 1170 m/sec (4212 km/hr); deceleration of the nose cone began at the 270th second after launching; parachute system began operation at 337th second of flight.	Unknown	b-2 k-5 p-1 p-3 s-5 y-1 y-6
Second stage; 9 rocket flights	1956 (perhaps 1953-1956)	Pair of dogs on each flight-total of 12 dogs (6 flown twice) in nonhermetic rocket compartments with ventilated pressure suits; dogs with protocols revealed include Linda, Malyshka, Al' bina, and Kozyavka	To 110 km altitude-nose cone separated from rocket at 188 seconds; (a) at 75-90 km altitude, corresponding to 247-250 seconds of flight, animal in right chassis (catapult truck) ejected at speed of 460-730 m/sec, and after 3 seconds of free fall parachute system operated with G stress of 7, and animals landed in 50-65 min; (b) at 39-46 km altitude, corresponding to 297-300 seconds of flight, animal in left chassis ejected at velocities of 1000-1150 m/sec, free falling to some 4 km, where parachute system went into operation; catapult trucks landed within radius of 3-70 km from launching site and were recovered usually within 3-8 hr after launching. (Authors differ somewhat in their data.)	Bugrov Petrov Yugov Gorlov Serov Yakovlev	a-3 b-1 b-2 f-1 k-5 p-1 p-3 s-4 s-5 y-1 y-6

(Table Continues)

Biological and Biomedical Experiments in Rockets and Satellites - USSR (Continued)

A. Vertical Rockets (Continued)

Experimental Stage and No. of Flights	Launch Dates	Biological Payload	Flight Summaries	Investigators	References
Third stage; (No. of rocket flights not apparent in literature)*	1957	Pairs of dogs, one normal and one anesthetized, total of 5 different dogs (some flown twice or even three times)- fastened to cradles (hermetically sealed cabins)	To 200-212 km altitude; maximum ascent speed of 1.72 km/sec, and descent speed of 1.75 km/sec; nose cone separated at peak of flight trajectory; at 4 km altitude, the nose-cone brake chute opened with stress of 8 G, and at 2 km altitude the basic parachute system operated with stress of 4 G; weightlessness lasted 360-370 seconds and ceased by the 400th-440th second; deceleration G-stress lasted 35-40 seconds; nose cone landed 605-660 seconds after launching.	Galkin† Kotova Petrov Chernov Gorlov Kosov Serov Yakovlev	f-1 g-1 k-5 p-1 s-5 y-1 y-6
Stage of further experiments - vertical geophysical research rocket - "the second launching of such a rocket."	Aug. 27 1958	2 dogs, Belyanka and Pestraya in felt-lined hermetic cabin; 3726 lb payload, greater than weight of Sputnik III	To 450-km altitude; rocket was stabilized "during the entire flight;" landed "in a selected area" safely, and recovered in good condition.	Unknown	a-3 k-5 p-1 s-4 s-5 y-6
Stage of further experiments; single stage rocket	Jul. 2 1959	2 dogs and a rabbit as part of heaviest payload (4400 lb) yet put into space; one of the dogs, Otvazhnaya, had been used in two earlier flights	Apparently to over 100 miles altitude; animals successfully recovered.	Unknown	a-4, s-5
Stage of further experiments; single stage rocket	Jul. 10 1959	2 dogs	Apparently to over 100 miles altitude.	Unknown	s-5
Stage of further experiments	Jun. 15 1960	2 dogs and 1 rabbit	Apparently to over 100 miles altitude.	Unknown	s-5

*The chronology of Soviet accomplishments in terms of the experimental stages reported (first stage, second stage, etc.) cannot be reproduced here accurately in view of divergent Soviet reports. Kousnetzov's reference to the "first stage" incorporates both the 1949-1952 and the 1957 experiments; his accounts of the "third stage" refer to experiments which others (Parin, et al.) report as having been performed in 1958 as part of a further experimental stage. Thus, the reader is left confused in attempts to interpret chronologically the Soviet "state of the art."

†The Galkin, et al., paper includes, it appears, accounts also of the "first stage" experiments; e.g., these authors report on 14 dogs, whereas the Yazdovskiy paper reports that experiments in this "third stage" were conducted with 5 dogs. Accordingly, it is presumed that Galkin, et al.'s 14 dogs include the 9 dogs employed for the "first stage."

(Table Continues)

Biological and Biomedical Experiments in Rockets and Satellites - USSR (Continued)

A. Vertical Rockets (Continued)

Experimental Stage and No. of Flights	Launch Dates	Biological Payload	Flight Summaries	Investigators	References
Stage of further experiments; rocket	Jul. 1960	Not known, but included dog Otvazhnaya, who made 5th successful rocket flight	Apparently to 130 miles altitude.	Unknown	s-5
		B. Satellites			
Sputnik II, satellite, launched by multi-stage rocket	Nov. 3 1957	Dog Laika, 6 kg. female, 2 yr old, in hermetically sealed conical-shaped aluminum alloy chamber payload wt of 1120 lb, or 6 times greater than Sputnik I	The first orbital flight of a living subject; to 1,038 miles apogee at 15,000 mph; to 140 miles perigee at 18,000 mph; orbit period of 103.7 min; Laika lived in satellite throughout period of established program; death on 6th day assumed to occur due to hypoxia; satellite disintegrated Apr. 14, 1958.	Chernov Yakovlev	a-2 b-2 c-2 f-1 h-3 h-4 j-1 k-5 n-6 s-5 y-1 y-6
First Spaceship Satellite	May 15 1960 Landing not intended	Astronaut cabin try-out	Total weight 4540 kg; perigee 312 km; apogee 369 km; period 91.2 min; flight time 96 hr; revolutions 64 before command to descend. On this command the ship rose instead of descending.	Unknown	a-11
Second Spaceship Satellite (1960 Lambda; Sputnik V) launched by multi-stage rocket.	Aug. 19 1960 Aug. 20 1960	Capsule load: 2 female dogs, Belka - 4.5 kg, and Strelka- 5.5 kg; 6 black and 6 white mice; Drosophila (D-32 & D-18); Tradescantia; seeds of variety 186 wheat; three varieties of of pea seeds, two varieties of corn, onion, Allium Fistulosum and Nigella; Actinomyces; Chlorella; cultures of K-12 bacteria coli; variety of "V" and "aerogenes" bacteria coli; T-2 and	Total weight 4600 kg. The first sucessful orbital flight and recovery of living subjects from space; perigee 306 km; apogee 339 km; period 90.72 min; flight time 24 hr; revolutions 17. Carrier and capsule recovered less than 7 miles from predetermined point, after traveling 437,500 miles; all the numerous cytological, genetic, and microbiological objects were	Unknown	a-7 a-11 h-5 h-6 n-1 s-5

(Table Continues)

B. Satellites (Continued)

Experimental Stage and No. of Flights	Launch Dates	Biological Payloads	Flight Summaries	Investi-gators	Refer-ences
Second Spaceship Satellite (1960 Lambda; Sputnik V) launched by multi-stage rocket. (Continued)		13-21 bacteriophage strains; HeLa cells; human and rabbit skin samples; desoxyribonucleic acid from goiter gland of calf; Carrier Spaceship load: 15 black and 15 white mice	returned from the flight alive; the first postflight observation of animals "made it possible to conclude that no noticeable deviations in the condition and regulation of the main physiological functions from the usual level recorded under laboratory conditions occurred in the animals."		
Third Spaceship Satellite (1960 Rho)	Dec. 1 1960 Dec. 2 1960	Repetition of research program of second spaceship: 2 dogs; Pchelka, Mushka; a variety of other animal and plant life	Total weight 4563 kg; perigee 180 km; apogee 88.47 km; period 88.47 min; flight time 24 hr; revolutions 17; systems operated normally; ship destroyed during reentry.	Unknown	a-11 n-4
Fourth Spaceship Satellite	Mar. 9 1961	Dummy cosmonaut; dog; mice; guinea-pigs; frogs; insects; seeds of plants and other biological objects	Total weight 4700 kg; perigee 183 km; apogee 249 km; period 88.5 min; flight time 1 hr 45 min; revolutions 1. Ship landed successfully by command in the assigned area.	Unknown	a-11
Fifth Spaceship Satellite	Mar. 25 1961	Repetition of biological research program of fourth ship	Total weight 4695 kg; perigee 178 km; apogee 247 km; period 88.42 min; flight time 1 hr 45 min; revolutions 1. All systems operated normally, and cabin with animals and dummy was successfully landed by command in the assigned area.	Unknown	a-11

(Table Continues)

B. Satellites (Continued)

Experimental Stage and No. of Flights	Launch Dates	Biological Payload	Flight Summaries	Investi-gators	Refer-ences
Spaceship Satellite "Vostok"	Apr. 12 1961	First orbital flight of man	Total weight 4725 kg; perigee 181 km; apogee 327 km; period 89.34 min; flight time 1 hr 48 min; revolutions 1. Cosmonaut pilot Major Yu. A. Gagarin made the flight brilliantly and landed sucessfully in assigned area.	Unknown	a-11

a-1 Anonymous, "Rocket flights of mammals to 200,000 ft," J. British Interplanet. Soc. 12:6-9 (1953)

An account of the V-2 and Aerobee missile flights from White Sands Proving Grounds under the senior project officer, Dr. J. P. Henry.

a-2 Anonymous, "Sputnik II through Russian eyes," Astronautics 3:48-49, 62 (1958)

Although silent on launching vehicle and means of propulsion, these translations from the Soviet press offer hitherto unreleased data on structure of the satellite and the biological experiments performed.

a-3 Anonymous, "Soviets recover research rocket dogs," Aviation Week 69:61-63 (Nov. 3, 1958)

Izvestia reports two dogs, Belyanka and Pestraya, were recovered from 280 miles altitude in a single-stage research rocket launched from the "the middle latitudes of Soviet European territory" on Aug. 27, 1958, with a 3,726-lb payload. This is reported as being the second launching of such a rocket. The felt-lined cabin, which landed "in a selected area," contained "a regeneration system, a self-contained system for recording the biological functions of the animals, and a special motion picture camera." The rocket was stabilized "during the entire flight, including the intertial part of its flight," to ensure the necessary conditions for the experiment. The rocket also carried instruments for measuring concentration of free electrons, ion composition of the atmosphere, concentration of positive ions, electron temperature, air pressure, micrometeorite impingement, ultraviolet region of the solar spectrum, infrared radiation of the earth, and the earth's atmosphere.

a-4 Anonymous, "Rabbit and two dogs recovered from space," Science 130:258 (1959)

From Soviet announcements, two dogs and a rabbit on a 4400-lb payload were launched into space on July 2, 1959, and successfully recovered. According to the Soviet press, instruments aboard the missile sent back information on the animal's reaction to weightlessness, and information on the ultraviolet part of the solar spectrum, the structure of the ionosphere, and the direction and speed of air streams at various altitudes. Among commentator's reports: "This has proved we can bring animals back alive," and, "It means much in the preparation for space flights by human beings."

a-5 Anonymous, "NASA's NERV works agency's first West Coast shot this month," Western Aviation 40:30-31, 66 (Aug. 1960)

The instrumented payload is the General Electric NERV (Nuclear Emulsion Recovery Vehicle) which weighs 75 lb and contains a package with 21 layers of special emulsion to provide a visual record of the characteristics of ionization particles in the 10 to 150Mev range. The NERV measures the low-level radiation intensity to gain a complete profile of the belts. Emulsions will be exposed by a telescoping cylinder at 200 miles altitude. Exposure will continue through an estimated apogee of 1700 miles. An electric motor is used to rotate the emulsion cylinder 360 degrees. Four NERV shots are planned, two each from West Coast and Cape Canaveral.

a-6 Anonymous, "Mice to be bred after trip into Van Allen belts," Missiles and Rockets 7:36 (Oct. 24, 1960)

Medical and nuclear authorities are closely scrutinizing some 600 lb of experiments which traveled 650 miles into the Van Allen belts. Three mice and over ten other experiments rode in a GE RVX-2A nose cone on an Atlas missile to 5000 miles down the Atlantic Missile Range and were recovered several hours after impact. Results of some of the experiments will be known within weeks. The mice so far have shown no ill effects and no premature graying from their exposure to radiation. Moe will be mated to Amie or Sally to study genetic effects. Complete results on the mice will require about a year. Physiological data telemetered for the first 17 minutes of the half-hour journey showed normal heart beat, temperature, and muscular movement, except for a brief moment at launch. Only one of the females wore the bioinstrumentation package. A separate experiment determined the rate at which radiation in the Van Allen belt would enter the human skin.

a-7 Anonymous (Nontitled), Discovery XXI:482-486 (1960)

A concise summary with illustrations of the experiments carried out in Sputnik V, launched Aug. 19, 1960, based on information from official Russian sources. The biomedical experiments carried out in the 10,000-lb satellite were designed to provide data on specific features of the vital activity of different animal and plant organisms during a space flight, the biological action of space-flight conditions on living organisms (overstrain, prolonged weightlessness, the transition to and from weightlessness), the action of cosmic rays on the vital activity and heredity of animal and plant organisms, systems for maintaining life and well-being during space flight (air regeneration, temperature regulations, food and water supply, sanitation, etc.). In addition to dogs, Belka and Strelka, the biological payload included 21 black and 19 white mice, the seeds of different varieties of onions, peas, wheat, and maize, Nigella, actinomycete fungi, Chlorella in liquid and solid nutritive media, sealed ampules of cultures of intestinal bacteria (type KK-12, B, "aerogenes"), butyric fermentation bacteria, a culture of staphylococci, two varieties of phages (T-2 and 13-21), DNA, HeLa cells, and pieces of preserved human and rabbit skin. Also, the container carried four automatic bioelements with a culture of butyric fermentation bacteria, two enclosed in a sperical thermostat and two in an unheated container. The various microbiological and cytological specimens were intended to provide data on the effect of space-flight conditions on growth and genetic change. The oxygen concentration was to be maintained at 20 to 25 percent, with a carbon dioxide concentration no higher than 1 percent; the temperature was to be between 15° and 25°C, the relative humidity at 39 to 70 percent, and the pressure at one atmosphere. The feeding method was similar to that used with Laika. The physiological information recorded during the flight included arterial blood pressure, electrocardiograms, frequency of respiration, body temperature, and movements. Data transmitted to earth stations by radio-telemetry included cabin temperature, pressure, humidity, and control data on the functioning of the life-support system. Television was employed to study the motor activity of the dogs, and transducers mounted on each cradle provided additional data on their movements. Ionizing radiation dosimeters placed near the dogs and on their suits measured radiation dose from cosmic rays. Pre- and post-flight studies included metabolism, blood and urine, cardiovascular, immunological, and (for the rats only) nervous activity and their typological peculiarities. The postflight examination showed that the rats, like the dogs, took the trip well. The Arknik also investigated cosmic radiation and short-wave solar radiation. Measurement techniques and some experimental results are given.

a-8 Anonymous, "Discoverer XVIII," Missiles and Rockets 7:15 (Dec. 19, 1960)

The latest Discoverer capsule, carrying a biological payload, was recovered Dec. 10, after 48 orbits in three days. Some seven hours before launch a massive solar flare began and lasted for the first 13 hours of the satellite's orbital flight. The specimens

received up to 30-35 RAD during their period in space. Radiation dosimeters indicated that the specimens received no lethal dose. Previous estimates of the radiation level of such flares put the dose at intensities fatal to specimens unless protected by heavy shielding. Some specimens were encased in different types of metals to test shielding properties. Some were shielded only by the thin aluminum covering of the specimen capsule and the recovery vehicle. These apparently fared better than those protected by lead shielding, indicating that aluminum may be the more effective shielding material. Results of the Discoverer XVII launch indicated that biological specimens, including man, may be able to withstand heavy solar flares with a minimum of shielding.

a-9 Air Force Missile Development Center, Historical Branch, "The beginnings of research in space biology at the Air Force Missile Development Center, 1946-1952," AD 208018, Holloman AFB, New Mexico:USAF, ARDC, 1958

The first installment toward fulfilling theneed for examining the history of Air Force participation in space-biology research. A serious study of the origins of biological projects, 'their gradual evolution, and their scientific and technical contributions is of considerable value in avoiding old mistakes or duplicating previous efforts, and for suggesting new paths of endeavor in the planning and pursuit of the more complex programs required in the immediate future. The V-2 and Aerobee rocket experiments and balloon flights are reviewed, with emphasis upon the biomedical information obtained therefrom. Experiments included fungus spores, fruit flies, mice, hamsters, cats, dogs, and monkeys as subjects. The effect at high speed and altitude of G forces, subgravity, and cosmic radiation were major factors explored. Experience gained in rocket and balloon launching, instrumentation and recovery techniques, and the growing collection of scientific data particularly related to cosmic radiation and subgravity problems marked the practical beginning of Air Force research in space biology. (Abstract identical with abstract A-5).

a-10 Air Force Missile Development Center, Historical Division, "History of research in subgravity and zero-G at the Air Force Missile Development Center, 1948-1958," Holloman AFB, New Mexico:USAF, ARDC, 1958

A summary of subgravity flight employing animals in V-2 and Aerobee rockets, and in aircraft flights employing animals and men in Keplerian trajectories at HAFB, as well as a general summary of previous subgravity experiments during flight.

a-11 Air Information Division, Science and Technology Section, "Further details on Gagarin flight," AID Report 61-113, July 27, 1961

The present brief report recounts certain details found in three articles published by USSR scientists and discusses the implications of this information. The first article was written by Professor G. V. Petrovich and published in the Vestnik of the Academy of Sciences USSR. The second is a TASS interview with Professor V. V. Dobronravov. The third was written by Inna Yavorskaya, scientific secretary of the Interplanetary Travel Commission of the Academy of Sciences USSR.

b-1 Bugrov, B. G., Petrov, A. V., Yugov, Y. M., Gorlov, O. G., Serov, A. D., and Yakovlev, V. I., "Preliminary results of scientific investigations carried out with the aid of the first Soviet artificial earth satellites and rockets. Part III. Medico-biological investigations with rockets, Investigations of the vital activity of animals during flights in a nonhermetically-sealed cabin to an altitude of 110 kilometers," In Sbornik Statey (Collected Reports) No. 1, 1958

The aims of this work were to determine: (1) the effectiveness of using a pressure suit for sustaining life in the case of dehermetization of the cabin under conditions following an extended (up to one hour) stay at 110-km altitudes, (2) the possibility of releasing

the cabin by means of a catapult with velocities of more than 100 m/sec at altitudes of 80-90 km, (3) the character and degree of the effects of specific factors of flight on a living organism while in the upper atmosphere. Subjects were 12 dogs, weighing four to five kilograms. Six of them flew twice. To study the direct effect of flights upon the subjects during the entire time from rocket launch to animal landing, automatically recorded were maximum and minimum blood pressure, pulse rate, respiratory rate, and body temperature. For studying the more remote aftereffects of flights, particularly to determine their effect on the hemopoietic system and heart activity, pre- and postflight tests consisted of EKGs and clinical blood analyses. Essential conclusions were: maskless pressure suits ensured safe flight, and catapulting and parachute systems ensured safe recovery of the animal; failure of certain registration systems occurred as a function of strong vibrations in the initial moment of launching; it was not possible to note any regular pattern in the arterial pressure change during the free-fall period—arterial pressure rose in some cases and dropped in others; pulse-rate variations observed during active flight seem to be determined by individual nervous-system characteristics of each animal; in a number of cases changes in cardiovascular and respiratory function were accompanied by passive-defensive (urination-defecation) reactions; there were no notable differences between pre- and post-flight blood analyses; the results of the ESR index variation prevented well-founded conclusions as yet from the relatively limited material; no changes in the animals' general condition, skin, or hair pigmentation which might be related to cosmic radiation could be found; six to seven months' postflight observations revealed no notable changes in the behavior of the animals; the need for improved registration apparatus was made clear.

b-2 Burch, G. E., and Gerathewohl, S. J., "Some observations on heart rate and cardiodynamics during weightlessness," Special report, CSCRD-16-5, Washington, D. C.: USAMRDC, 1959

Considerable efforts were made during the last decade to determine the biomedical effects of subgravity and zero G. Animals and men were exposed to short and moderate periods of weightlessness, and their behavior, respiration, and cardiovascular functions were recorded during aircraft and rocket trajectories. The electrocardiogram was also recorded from subjects during increased and decreased acceleration on the subgravity tower. By and large, a marked increase in cardiac rate occurred in almost all of the subjects during the acceleration and deceleration phases; this holds for aircraft trajectories as well as for the liftoff and reentry maneuver of rockets. However, the EKG generally appeared normal during the free-flight periods and weightlessness, although some slight changes of its elements occasionally were observed. In several cases, the heart rate was somewhat increased and unstable during postacceleration weightlessness; thereafter, it returned to normal. That psychological factors entered into the phsyiological phenomena is clearly evident through an analysis of the data obtained in zero-G experiments. Nevertheless, the entire integrated responses resulted in subjects whose cardiological states remained sufficiently sustained to ensure normal and controlled behavior.

c-1 Champlin, G. A., and Wilbarger, E. S., "Bio-Flight project 2B," revision I, CSGRD-16, Washington, D. C.:USAMRDC, AOMC, Sept. 10, 1958 - July 10, 1959

This project was readied on a noninterference basis as an inclusion in the weapons system Test Nose Cone Recovery of Jupiter AM-18, fired on May 28, 1959. The report includes a detailed, preliminary inspection of the results of biological measurements. Not included are details of physical systems, preliminary tests, flight preparations, or instrumentation. These are subjects of previous reports and reports to be published later. Bioflight Project 2 consisted of two main tasks. In the latter phases of development they were distinctly separated for operational facility; the Naval School of Aviation Medicine assumed the principal role in the final preparation of experiment 2A (Baker), and the bioastronautics Research Unit prepared experiment 2B (Able).

In flight, the following measurements were programmed:

Able: (1)electrocardiogram;* (2) electromyogram, extensor; (3) electromyogram, flexor; (4) heart sounds; (5) pulse velocity, femoral vs carotid;* (6) respiratory rate; (7) body temperature; (8) ambient temperature; (9) ambient capsule pressure; (10) relative humidity;* (11) percent carbon dioxide; (12) monitor electric shock;* (13) monitor lever response;* (14) monitor light stimulus;* (15) monitor camera; (16) emulsion plates for heavy nuclei of cosmic origin. (Difficulties were experienced in measurements marked by an asterisk.)

Baker: (1) electrocardiogram; (2) respiratory rate; (3) body temperature; (4) ambient temperature; (5) ambient capsule temperature; (6) emulsion plates for heavy nuclei of cosmic origin. All these measurements were received during the total duration of the flight.

Five types of information were utilized in obtaining the results presented in this report: (1) direct inspection; (2) gauge reading; (3) brush recording of measurement signals; (4) electromagnetic tape recording; (5) photography.

The description of the observations is like the information given in Ref. g-4. The five basic biology capsules flown with 2B and containing fruit-fly pupae, onions, mustard and grass seed, Escherichia coli and other bacteria, and corn were recovered intact and returned for study.

c-2 Chernov, V. N., and Yakovlev, V. I., "Research on the flight of a living creature in an artificial earth satellite," ARS J. Supplement 29:736-742 (1959)

This appears to be as complete a single report as is available in the English language on the experimental results of Laika's orbital flight of Nov. 3, 1957, in Sputnik II. Soviet technical and scientific accomplishments preceding the flight are included. Described and discussed in some detail with illustrations are the cabin for the animal, its equipment and experimental apparatus, and the preparation and training of experimental animals. Results of the experiment are examined with regard to three basic periods: the preflight period, the launching of the rocket and the satellite's escape into orbit, and the orbital flight of the satellite. During the preflight period, Laika's behavior, as well as the indices of the functioning of the cardiovascular and respiratory systems, in no way differed from the ordinary and did not exceed the observed normal limits. During the launch period and at the height of acceleration, no perceptible motor disturbance was observed. Immediately after launching, systole frequency increased three times in comparison with the initial frequency, but later decreased while acceleration continued. No pathological signs were observable from analysis of the electrograms. "The observed pattern was merely characteristic for a heightened frequency of heart beats of reflex origin." Respiratory rate at the maximum values of acceleration was three to four times the initial frequency, and in the more rapid respiration there were observed mechanical respiratory difficulties due to the effect of acceleration. Origins of the changes in physiological functions are ascribed to reactions in the nature of defensive reflexes specifically influenced by the irritants of vibration and noise. "For this reason the systolic frequency remained at a higher level than normal." During the orbital period and period of weightlessness the frequency of respiration decreased. "After a very brief and insignificant acceleration of heartbeat (as a result of the cessation of acceleration and vibration), the frequency of systole continued to decrease and to approach the initial rate. However, the time required for the heartbeat to return to normal after acceleration stopped was approximately three times as much as in our laboratory experiments, where the animal was subjected in the centrifuge to the same accelerations as those in the satellite." This flight result is ascribed to the state of weightlessness, resulting in changes of afferent impulses to the CNS; a change in the functional state of the subcortical formations which regulate circulation and respiration, and also to the possible effect of noise and vibration intensities, which were higher in launching than in the laboratory experiments. The electrocardiogram did not bear a pathological character and was connected with the increased functional overload during the period preceding weightlessness. The motor activity of the animal during weightlessness exhibited the normal pattern. "The fact that the indices showing the functioning of circulation and respiration became normal during the period of weightlessness testified to the fact that this unique factor in itself did not cause any essential changes in the

condition of the physiological functions of the animal. Certain deviations of the functional indices which were observed later must apparently be explained by the change of air temperature in the airtight cabin." The supply of oxygen was completely adequate during the period of flight. The fact that there was no decrease in pressure indicated that the cabin was airtight. Cabin construction and sturdiness guaranteed protection from meteorite material. It is concluded that an evaluation of the results obtained gives every evidence that living creatures can satisfactorily survive conditions approaching those of cosmic flight.

c-3 Clamann, H. G., "Biological experiments with space probes," in Konecci, E. B., "Review of January 1961 Lectures in Aerospace Medicine - USAFSAM," Santa Monica, California: Douglas Aircraft Co., 1961

In a major portion of this paper, the author defines more closely the criteria for selecting feasible biological specimens and biological space probes. One example of a biological space probe (Atlas ballistic shot of Oct. 13, 1960) is described in detail, and preliminary results of the three-mice experiment (Project MIA) are presented. The pulse-rate data of one mouse during the total flight is interpreted, viz., "As a certain surprise, the pulse rate is influenced much more by vibration and noise than by even the high G force at reentry. The pulse rate climbs directly after ignition of the rocket and decreases even before burnout. At reentry, the pulse rate climbs to a peak long before the G force reaches its maximum. During weightlessness, the pulse rate remains fairly constant and resembles the pulse rate found during sleep."

c-4 Crawford, G. W., "Radiobiological experiments in Discoverer satellites," in Konecci, E. B., "Review of January 1961 Lectures in Aerospace Medicine—USAFSAM," Santa Monica, California:Douglas Aircraft Co., 1961

The SAM recoverable biopack experiments on a "piggy-back, noninterference" basis on Discoverer satellites XVII and XVIII, launched on Nov. 12 and Dec. 7, 1960, respectively, resulted from a challenge to develop meaningful biological and dosimetric spore experiments. Biological specimens included conjunctival and synovial cell cultures, bacterial spores of Clostridium sporogenes, algae, human gamma globulin with rabbit antiserum specific for it, nerve tissue and Neurospora. Both capsules were recovered from successful orbits. A solar flare occurred on the Discovered XVII launch date. When the final reports are available from the various neutron monitors aboard balloon and rocket flights, and from ionospheric absorption studies, it will be possible to draw a more complete picture of the solar flare which can be correlated with the radiation measurements and effects on the biological specimens of the SAM biopack.

c-5 Crawford, G. W., Pizzuto, J. S., Logie, L. C., Dexter, C. R., and Kohr, C. M., "Radiobiological experiments in Discoverer satellites. I. Physical dosimetry," Konecci, E. B., "Review of January 1961. Lectures in Aerospace Medicine - USAFSAM, Santa Monica, California:Douglas Aircraft Co., 1961

Dosimeters selected were nuclear track plates, Kodak neutron-sensitive NTA film, Dupont emulsion film, silver-activated glass rods, two-phase and single-phase tetrachloroethylene chemical dosimeters, alanine, albumin, antimony foil, and gold foil. By careful analysis of the data, it is attempted to: (1) identify the ionizing radiations producing the response in the dosimeters, and (2) measure a meaningful dose. While the study is still incomplete, several observations as a result of flights XVII and XVIII are made. Discoverer XVII - the flux of a solar flare exposed the biological samples to 8×10^8 protons per square centimeter. Disregarding local increases in dose from secondaries created in heavy metals, the measured radiation dose ranges from 16 to 33 RAD. Discoverer XVIII - the dose was much too low for accurate measurement, but was estimated to be between 0.4 and 0.6 RAD equivalent 730 Mev protons.

d-1 Davis, I., and Roberts, T.L., "Microbiological effects of space radiation. II. Physiological changes and lethality observed in Clostridium sporogenes following the Discoverer XVII satellite space flight," presented at the "Lectures in Aerospace Medicine Symposium at the School of Aerospace Medicine January 16-20, 1961," Brooks AFB, Texas:SAM, 1961; reprinted in part in Konecci, E.B. "Review of January 1961 Lectures in Aerospace Medicine," Santa Monica, California:Douglas Aircraft Co., 1961

The preflight handling operations and environment encountered had very little or no effect on the spore system, attesting to the extreme stability of this biological system for space experimentation. The spores on this flight clearly show a significant inhibition of the usual effect produced by caramelized glucose treatment. This inhibition of labilization expressed by the spores 90 minutes after treatment is interpreted as an effect of the space-radiation dose encountered by the biological specimens. To the knowledge of the investigators, this is the first microbiological system that has been returned from space which shows positive results that possibly may be correlated with radiation dosimetry. This study suggests that the Clostridia spore labilization system may find use as a biological index of space-radiation hazards.

d-2 DeBusk, A.G., "Genetic studies in the lower radiation belt," preliminary draft, Tallahassee, Florida, Florida State University, Genetics Laboratories (not dated)

Preliminary genetic and physiological studies of conidia of Neurospora crassa exposed to flight conditions for 26 minutes penetrating to an altitude of 1108 miles into the lower radiation belt are reported (NERV No. 1 flight of Sept,.19, 1960). A surprisingly high level of mutation was noted in the experimental cells when compared with three sets of control cells. A further unexpected phenomenon referred to as "physiological injury" could be reversed at least partially by certain organic acids which are known to function in cellular energy conversions. It was not possible to determine what specific factor of flight, if any, contributed to or caused the phenomena observed.

d-3 DeBusk, A.G., "Preliminary report of genetic studies on Discoverer XVIII," Tallahassee, Florida, Florida State University, Genetic Laboratory (not dated)

Primary aim of the study was to attempt to correlate transversal of primary cosmic rays with an increase in mutation in the population of cells lying along the track path. The test system employed layers of Neurospora conidia. Due to faulty emulsions on the experimental plates, the major aim of the experiment could not be fulfilled, although an attempt was made to salvage some useful data. No reverse mutation was observed at the inositol locus in either the experimental or control population examined. The phenomenon of "physiological cell injury" observed in NERV No. 1 shot (Sept. 19, 1960), which penetrated deep within the lower Van Allen belt for some 26 minutes, has not been observed in preliminary studies of cells exposed in Discoverer XVIII (Dec. 7, 1960). Furthermore, no significant increase in forward mutations was observed in the experimental cell population examined to date.

d-4 Directorate of Bioastronautics Projects, "Discoverer III. Biomedical data report," WDZPB Report No. 2, Los Angeles, California:HQARDC, AFBMD (not dated)

A discussion of the data gathered from Discoverer III, launched from Vandenberg AFB, June 4, 1959. The primary objective of this biosatellite launch was to recover living specimens (four C-57 black mice) from orbital space flight. Secondary objectives were to investigate the response of living specimens to conditions of launch, orbit, and recovery, to confirm engineering design for life-support systems, to modify design based on experiences with ground holding facilities, and to develop countdown and capsule-assembly procedures prior to launch.

A miniature transmitter designed at SAM was mounted with battery in a saddle affixed to the back of each mouse. Electrophysiological signals generated from cardiac

potentials were sensed by electrodes imbedded in thorax and abdomen; a miniature coil mounted on each flank of the specimen sersed respiratory as well as general body movements. Detectors located outside each cage were tuned to the specific transmitter frequency selected for each mouse. Each viability signal was amplified separately and transmitted on separate telemetry channels. Also provided were sensors for monitoring capsule pressure, temperature, humidity, oxygen-bottle pressure, noise, and acceleration. All parameters but noise and acceleration were to be telemetered on each orbit passing over tracking stations. After separation of the biomedical recovery capsule from the Discoverer vehicle and initiation of reentry, telemetry was programmed to cease, and it was anticipated that an eight-channel on-board tape recorder would monitor viability, capsule pressure, temperature, acceleration (three tape channels), noise, and time.

It was anticipated that the second stage would remain on polar orbit at 150 nautical miles altitude for 27 hours, but technical problems prevented successful achievement of orbital velocity, and premature reentry down range ensued. Thus, the primary biomedical mission objective was not achieved. However, all four mice lived through the stresses of launch and accelerative forces and through more than 500 seconds of weightlessness. Specimen activity correlated with ignition and burn-out of each stage, and marked activity occurred during weightlessness. Respiration and electrocardiograph patterns could not be differentiated because of amplifier oscillation in all channels. But a late modification in vehicle telemetry allowed transmission of one viability signal over a high-frequency-response channel (1000 cps) following burn-out of the second-stage engine. With this channel, 29 seconds of EKG were reproduced from one animal during the ballistic trajectory. No abnormalities were noted, and cardiac rate varied from 556 to 592 cycles per minute. The life-support system functioned satisfactorily from lift-off to 790 seconds.

Part or all of the secondary mission objectives were achieved. While the degree to which monitoring of specimen viability and cell environment was accomplished was rather severely limited due to an insufficient number of telemetry channels and inadequate bandwidths of those channels that were available, the experience gained from this effort emphasizes the real requirement for a high order of priority of biomedical data collection and instrumentation in future vehicle design. Data were obtained which further demonstrate lack of untoward responses to weightlessness. For the first time, a professional military medical crew conducted the assembly and prelaunch checkout of a life-support system with specimens for an orbiting vehicle. Refinement of design of ground holding facilities for animal and manned flights has developed from this program. Countdown procedures and principles for handling bioastronautic vehicles have evolved from repeated practice launch activity. It is concluded that the abundant success of secondary objective achievement justifies the enormous effort expended and enhances the probability of success of subsequently planned biosatellites of the Discoverer series.

f-1 Flickinger, D., "Results of animal investigations in space vehicles to date," presented at 30th Annual Meeting, Aeromedical Association, Los Angeles, California, Apr. 27-29, 1959

The material analyzed for this summary was contained in relatively few reports (literature dated 1949 through 1959), since the criteria set forth required that only those experiments be included which utilized rocket-engine thrust to propel the biopack into space equivalent atmospheres. This stipulation was made in order to provide pertinent data on not only the biological effects of the space environment itself but also those induced by the dynamic vehicular forces contained in the total flight. Three Russian (Galkin, et al., Bugrov, et al., and Chernov and Yakovlev) and three American (The Henry Group, Van der Wal and Young, and Army Navy Bioflight Project No. 1) reports of working groups are summarized, with major highlights abstracted in order of their date of publication.

f-2 Flume, J. L. "Radiobiological experiments in Discoverer satellites. V. Effect of space flight on the in vitro combining capacity of antigen and antibody," presented at the Lectures in Aerospace Medicine Symposiun at the School of Aerospace Medicine, Jan. 16-20, 1961; Brooks AFB, Texas:SAM, 1961

Samples of human gamma globulin and rabbit antiserum specific for human gamma globulin were dried onto small squares of filter paper and mounted on both emulsion surfaces of nuclear track plates. The squares were immobilized by means of a thin lucite plate, and the entire package was wrapped in black covering. Two such packages were successfully flown in the nose cone of the Discoverer XVII. Upon recovery, materials were eluted from the paper in saline and reactivity determined by means of passive hemagglutination. The only effect observed was an increase in reactivity in both antigen and antibody in the flight package. No inhibitory effect due to irradiation was detected.

f-3 Fraser, L. W. and Siegler, E. H., "High altitude research using the V-2 rocket," Bumblebee Report No. 81, Silver Spring, Maryland:Johns Hopkins University, Applied Physics Laboratory, March 1946 - April 1947

The report includes the results of an experiment conducted to determine in a preliminary way whether or not the cosmic rays, or other phenomena of high altitude, had any unusual effects on the growth and mutation of fungus spores. Spores having a short life cycle were provided by NIH and were flown on Dec. 17, 1946, in missile No. 17 on the third flight in the series of five V-2 rocket experimental flights. A maximum altitude of 114 miles was reached. The spores were not recovered.

g-1 Galkin, A. M., Kotova, A. R., Petrov, A. V., Chernov, V. N., Gorlov, O. G., Kosov, I. I., Serov, A. D. and Yakovlev, V. I., "Investigation of the vital activities of animals during flights in hermetically-sealed cabins to an altitude of 212 kilometers," Sbornik Statey No. 1, 1958; Washington, D. C.:U. S. Joint Publications Research Service, JPRS/DC-288: 5-28, 1958

Medico-biological investigations during rocket flights into the atmosphere have been conducted systematically in the Soviet Union since 1949, for the purpose of studying shifts in certain physiological functions, behavior of the animals during flight, and any bodily changes as a result of the flights. In 1957, 14 dogs (only five dogs are listed, although some were flown two or three times) were flown in pairs (one anaesthetized, the other normal) in hermetically sealed biopacks on seven distinct flights to altitudes of 62 to 130 miles. Pre- and post-flight examinations included blood, chest X-ray, EKG, blood pressure, respiration and pulse, urinalysis, temperature, and body weight. Blood pressure, pulse, and respiration were registered during three-hour training periods in the cabin and during centrifuge training. A telemetric control system registered the compartment shell temperature, thermoinsulating lining, and barometric pressure inside the cabin. Physiological functions were measured by means of pickoffs, amplifying units, automatic pressure devices, electric clocks, and automatic optical recording devices. Motion pictures were taken at intervals during flight. The state of the physiological functions was not successfully registered during all parts of the flight projectory, inasmuch as abrupt changes in the direction of action G-stresses interfered with instrument operation and caused sharp animal movements which were reflected in the quality of the recordings. Some data are illustrated, although no data are cited for determining the extent of experimental successes.

Conclusions were as follows. (1) The vitally necessary conditions were guaranteed by the hermetically sealed cabin. (2) Acute disorder in the physiological functions did not occur, and no postflight changes in behavior were observed. (3) The pulse and respiration rates and the blood pressure of the conscious animals increased during the active part of the flights. During the period of dynamic weightlessness the registered physiological parameters were maintained at a high level for the first two to three

minutes, with a tendency to decrease. The physiological indices returned to their original level within four to five minutes after dynamic weightlessness had begun. In the anaesthetized animals, the pulse rate, respiration, and blood pressure did not differ from their original values during the period of weightlessness. (4) The recovery system guarantees safe landing, although additional work is necessary to insure stabilization and more favorable deceleration conditions during the nose section's fall from altitudes of 200 km and higher.

g-2 Gerathewohl, S. J., Downs, S. W., Champlin, G. A. and Wilbarger, E. S., Jr., "Bio-telemetry in the nose cones of U. S. Army Jupiter missiles," IRE Trans. on Military Electronics. MIL-4:288-302 (1960)

On Dec. 3, 1958, a South American squirrel monkey, and on May 28, 1959, a rhesus and a squirrel monkey, were launched in the nose cones of two U. S. Army Jupiter missiles. The experiments were done by scientists of the Army and Navy Medical departments and personnel of the ABMA. They were done on a noninterference basis with the main mission of the missile. The primary objective of the bioflights was to demonstrate that animals can survive ballistic flights unharmed, if an adequate life support is provided. The secondary aim was to design, construct, and test such a system, to develop countdown and launching procedures, and to recover the specimen after flight. Moreover, technical and scientific information on the physiological and behavior status of the animal was to be gained through telemetry. Although the first animal was lost, valuable data were obtained on the functioning of the biopackage during flight. They served to improve the second experiment, which added substantially to the understanding of the biomedical requirements for space flight. Moreover, Able and Baker were the first primates recovered unharmed from an operational IRBM nose cone after reentering the earth's atmosphere. The essential results are summarized as follows. (1) It has been demonstrated that primates can be launched in IRBM's and safely recovered in a selected target area, alive, alert, and unharmed. (2) Life-support systems fully capable of monitoring small primates have been developed and actually tested under rocket-flight conditions. (3) Sensing devices, amplifiers, and signal-monitoring electronic equipment have been actually applied for measuring and controlling biomedical and environmental parameters, while their small size, weight, power consumption, and efficacy were properly maintained. (4) Scientific information has been obtained which will contribute to the realization of manned space flight. The report gives pictures of the biopacks, wiring diagrams, and graphic pictures of the results.

g-3 Gerathewohl, S. J., "Zero-G devices and weightlessness simulators," Publication 781. National Academy of Sciences - National Research Council, Washington, D. C., 1961

Concerns the devices methods, and techniques which have been used for the investigation of the effects of zero G and weightlessness by many investigators. Part I deals with devices which can be used for producing sub- and zero-gravity, viz., vertical-motion devices, aircraft, and ballistic missiles. A simple mathematical treatment of the physical parameters involved in sub- and zero-G conditions precedes the discussion of each of these three methods. In Part II, instruments and techniques for the simulation of weightlessness are described. The objective of this survey is to assure maximum usefulness of such devices and optimum cooperation between agencies, and to guarantee that new requirements of the future be incorporated in research proposals on bioastronautics.

g-4 Graybiel, A., Holmes, R. H., Beischer, D. E., Champlin, G. E., Pedigo, G. P., Hixson, W. C., Davis, T. R. A., Barr, N. L., Kistler, W. G., Niven, J. I., Wilbarger, E., Stulken, D. E., Augerson, W. S., Clark, R., and Berrian, J. H., "An account of experiments in which two monkeys were recovered unharmed after ballistic space flight," Aerospace Med. 30:871-931 (1959)

An account has been given of two experiments in which three monkeys were carried in Jupiter missiles 300 miles into space. In the first, a squirrel monkey (Old Reliable) survived in good condition until a mishap occurred to the vehicle on reentry. In the second, an American-born rhesus (Able) and a squirrel monkey (Baker) were recovered uninjured. Details have been furnished covering the construction of the biocapsules, the provisions for a closed-life support environment, the equipment and arrangements for monitoring the responses of the monkeys, and the experimental findings.

These experiments were carried out on a noninterference basis in missiles not designed for biological purposes. This necessarily imposed severe restrictions in space and weight and necessitated a long countdown time, 64 hours for the rhesus and eight hours for the squirrel monkeys. A short countdown period is a great advantage and a prime consideration in designing such vehicles for primarily biological purposes or for man.

Only a few measurements were obtained. More were planned for the rhesus monkey, but circumstances prior to flight voided some, and difficulties in flight several of the others. The chief objective was to recover healthy animals. To obtain "maximum results" the maintenance of the animal in a satisfactory state is a prerequisite for all determinations.

Ambient temperature and pressure within the capsules were monitored throughout flight, and the narrow limits of the variations observed demonstrated the adequacy of the equipment. Together with carbon dioxide and humidity control, the constancy of the animals' atmospheric environment was well ensured. This aspect of the experiment has direct application to man.

Chest sounds, respiratory rate, and the electrocardiogram were obtained on Old Reliable, the first two on Able, and the last two on Baker. Some difficulty was experienced in obtaining the respiratory signal during peak accelerations, and the phasic respiratory variations observed in the other records substituted at a few critical points.

Old Reliable and Able responded to the major events in flight with an increase in cardiac and respiratory rates during boost, a return to baseline values after cutoff, slight, brief increases at spin-up, and conspicuous increases at reentry. These changes seem to be compounded of a startle reaction followed by a more prolonged response. The nonpsychogenic influence was clearly evident during boost and reentry. Neither Old Reliable nor Able exhibited a significant fall of cardiac or respiratory rate below baseline values.

The deviant pattern of Baker involved variations above and below the baseline level. The cardiac response was a slight, brief increase in rate, followed by vagal inhibition. It was declared by an exaggeration of the normal sinus arrhythmia and twice by sinoatrial block. This was followed by lowering of the RS-T segment and T waves. An attempt was made to explain the findings on the basis of "fright without flight." This is thought to lead to a curious and ineffectual autonomic display characterized by reflex cardiac inhibition and peripheral vasodilation. This effect tended to mask the nonpsychogenic component of the response to stress.

Through a mishap to the vehicle on reentry, Old Reliable was lost, but Able and Baker were recovered about two hours after impact. The preparations to render first aid were unnecessary; "treatment" was limited to an injection of penicillin. Four days later Able died during the induction of light anesthesia for the purpose of removing the electrodes. Autopsy revealed no evidence of flight-related injury. This had the value of establishing the fact that unrecognized injury had not occurred. Baker, as of this writing, is alive and well. The only postflight medical treatment has been for intestinal parasites.

g-5 Green, C.D. "Studies of escape from ballistic space vehicles," with Welch, B.E., Brown, W.L., Lamb, L.E., Tang, P.C., Gisler, D.B., and Blodgett, H.C., "I. Biomedical evaluation," with Adams, R.M. and Dickey, J.R., "II. Instrumentation," Report 61-29. Brooks AFB, Texas:USAF Aerospace Medical Center, SAM, 1961

Biomedical information on primates successfully flown through programmed escape profiles was obtained in conjunction with the NASA project Little Joe. The purpose of the series of missile flights was to test equipment which had been designed to accomplish

escape separation of a future manned capsule from its booster vehicle. SAM participated in two flights - Little Joe No. 2, which tested the escape system at high altitude, and Little Joe No. 1-B, which involved escape at maximum dynamic pressure. The biological project (flight of two rhesus monkeys) was known as Project Hermes.

Hermes 1 (Little Joe No. 2) was launched on Dec. 4, 1959. Flight was successful, and the capsule was recovered. Maximum altitude was 280,000 ft; maximum acceleration produced by the activation of the escape rocket was plus 14.76 G. Maximum dynamic pressure was encountered during reentry at 289 seconds. The G force experienced was positive as a result of the vehicle's orientation on reentry.

Hermes 2 (Little Joe No. 1-B) was launched on Jan. 21, 1960, and following successful flight was recovered immediately. Maximum altitude was 49,000 ft and maximum acceleration encountered during firing of the escape rocket was plus 11.3 G. Maximum dynamic pressure was produced during an early phase of the flight. In both instances the "escape" rockets produced complex accelerations in the longitudinal and lateral axes of the animal as well as roll, pitch, and yaw.

The animals were 11X, a male, for Hermes 1, and 13X, a female, for Hermes 2. Animal responses during acceleration, deceleration, reentry, and water impact demonstrated survivability. Also recorded and evaluated were: (1) environmental data (i. e., relative humidity, total gas pressure, oxygen partial pressure, and gas temperature), (2) physiological data (i. e., respiratory rate, pulse rate, and cardiac rhythm from ECG tracings), (3) psychomotor performance data, (4) oculomotor movement. These experiments substantiate, under actual flight conditions, physical and biological design criteria for biopacks, physiological sensor response, and performance criteria during all phases of the ballistic trajectory and recovery operations from an impact area.

The changes in cardiac rate during the flight are consistent with previous experimental observations. Other studies, both in animals and humans, have demonstrated that during periods of stress there is an increase in cardiac rate; at the cessation of the G loading there is a return of the pulse rate to normal, and occasionally it falls below the pulse rate noted before the onset of stress. The alterations in respiratory frequency of 11X and 13X were consistent with those reported by other experiments. The accelerative forces during launch were not sufficient to inhibit respiratory movements completely. Rather, an increase in rate resulted. With a drop of acceleration to less than one G there was a prompt decrease in respiratory rate in both animals. As acceleration increased again, the respiratory rate also increased slightly and thereafter fluctuated within normal levels.

Hermes 1 and 2 were the first known rocket flights on which a psychomotor test was required of the animal. Animal 11X maintained work for longer than one minute of transverse G loading as high as six but stopped during the escape phase, when transverse G loading reach positive 14, combined with an imposition of both lateral and longitudinal G loading. The performance of 13X during the monitoring period and the launch phase was not as good as that of 11X. She also stopped work at the onset of the multiple accelerations of the escape phase. She returned to work after one-half minute; the performance record of the last six to eight minutes is of a high level and indicates that the animal suffered no persistent physiological deterioration as a result of the flight. Nevertheless, multiple stresses led to performance decrement during the flight.

The flight of Hermes 2 was the first occasion on which an attempt had been made to determine the possible development of nystagmus during missile flight. The first of two eipsodes of nystagmus apparently induced by the multiple accelerations of the excape phase, lasted at least 34 seconds. The only period of complete performance failure occurred coincidentally. The return of accomplishment of the psychomotor task was nearly instantaneous with the disappearance of nystagmic eye movements. The second period of nystagmus, of seven seconds' duration, occured at impact on the ocean and was not accompanied by performance failure. Animal 13X actually increased the rate of lever pull during the period, but no final conclusion can be drawn concerning the significance of nystagmus in a rhesus monkey as to its relation to manned flight. It would seem likely, however, that the animal would not have been able to perform a visual tracking test for at least one half minute period following "escape."

The instrumentation utilized consisted of devices for (1) sensing the life-cell temperature, the humidity, the atmospheric pressure, and the oxygen partial pressure, (2) detecting and measuring the subject's respiratory rate, pulse, eye movements, vectorelectrocardiogram, and psychomotor performance, (3) photographing the facial area of the animal during flight.

Specific details of the instrumentation system are discussed, as well as the design philosophy underlying the approaches used. Illustrations are included which indicate the scope and accuracy of data return.

h-1 Henry, J. P., Ballinger, E. R., Maher, P. J. and Simons, D. G., "Animal studies of the subgravity state during rocket flight," J. Aviation Med. 23:421-432 (1952)

This report summarizes the preliminary results obtained during four years of study of the various physiological reactions to subgravity by means of five V-2 and three Aerobee sounding rockets. Two types of study were conducted. (1) Physiological observations were made either of pulse and respiratory rhythm, or of arterial and central venous pressures, and data obtained on seven anesthetized Rhesus, Cebus or Cynomolgos monkeys. (2) Observations of performance were made on five mice by direct photography - a single mouse in a V-2 and pairs of mice in Aerobee II and III. The single mouse was presented a firm foothold on the wire gauze floor of a fixed cage, permitting reliance on his tactile and visual sense during the subgravity period. The aim of the Aerobee II experiment was to differentiate between the behavior of a normal and a labyrinthectomized mouse when both were deprived of adequate tactile and visual orienting stimuli by the 12-rpm rotation of the smooth-walled drum. The Aerobee III experiment was aimed at differentiating between the behavior of a normal animal provided with a firm foothold and that of one to whom both tactile and visual points of reference had been denied in a drum rotated at four rpm. In all V-2s and in one Aerobee, impact due to parachute failure caused instantaneous death, whereas satisfactory parachute deployment in the case of Aerobees II and III resulted in the recovery of live animals.

The results summarized are: (1) there was no evidence of a significant disturbance of the cardiovascular or respiratory systems; (2) photographic performance records of the five mice during two to three minutes of subgravity indicated that as long as a foothold was available they did not appear seriously disturbed. In all cases the animals ran and jumped normally immediately following resumption of an orienting gravity stress; (3) the weight of the evidence suggests that in currently attainable durations of two to three minutes the subgravity state will not lead to any serious psychophysiological difficulties. Investigations of the effects of subgravity states lasting for hours or days must await the development of orbital rockets.

h-2 Henry, J. P., "Physiological laboratories in rockets," Astronautics 2:22-26 (1955)

A capsule summary of methods and results of the monkey and mice experiments in Aerobee sounding rockets, including photos and description of the equipment installation in this upper-air research vehicle.

h-3 Hersey, I., "Dog in space," Astronautics 2:30-31 (1957)

Speculation on Soviet accomplishment leading to the firing of the 1120-lb Sputnik II satellite and its experimental purposes, based on limited Soviet announcements to date.

h-4 Hersey, I., "Soviet biological experiments," Astronautics 4:31, 80-81 (1959)

An annotated reproduction of the paper, "Some Results of Biological Experiments in Rockets and Sputnik II," presented by A. G. Kuznetzov, a leading Soviet physiologist, at the Third European Congress of Aviation Medicine at Louvain, Belgium, September 1958.

h-5 Hetherington, A. W., "A summary of the information received on the second Soviet biosatellite--1960 Lambda 1/Sputnik V," ARDC, Washington, D. C.:Andrews AFB, 1960

This compilation from numerous sources, most of them from Tass and/or Radio Moscow, covering interviews, press conferences, and background interpretive stories released during the period Aug. 19-27, 1960, reports the successful flight of the Arknik to a maximum altitude of 320 km, on near-circular orbit, initiated on Aug. 19, 1960, and terminated by successful reentry on Aug. 20, 1960, prior to the 18th revolution, after traveling 700,000 km, or approximately twice the distance from the earth to the moon. Precision of the guidance and braking system enabled landing the satellite itself, after ejection of the capsule, to within about 10 km of the calculated point. The weight of the satellite ship amounted to 4,600 kg. The biological payload contained three cages with two white laboratory rats, and 15 black as well as 13 white laboratory mice in the airtight cabin of the spaceship, whereas the ejected capsule contained the two dogs, Strelka and Belka, a cage with six black and six white laboratory mice, several hundred insects—Drosophila, the common fruit fly (D-32 and D-18), two vessels with Tradescantia plants, seeds of variety 186 wheat, three varieties of pea seeds, two varieties of corn, onion, Nigella, Actinomyces fungi, Chlorella, cultures of K-12 bacteria coli, a variety of "V" and "aerogenes" bacteria coli, bacteriophage of T-2 and 13-21 strains, HeLa cells, human and rabbit skin samples, desoxyribonucleic acid obtained from the goiter gland of a calf. A photo-emulsion device, designed to investigate the nucleus of "original cosmic radiation," was also aboard. The functioning of the heart, respiration, arterial pressure, and temperature of the dogs' bodies, as well as their movements, were registered. Television and special movement counters aided the behavioral and physiological studies. The entire telemetric system is said to have worked unfailingly. The condition of the dogs after landing did not differ from the condition observed during ground operation. It was established experimentally for the first time that animals endure normally the physiological stresses involved in the spaceship's descent from orbit and its landing. The condition of the organism during the spaceship's ascent, the influences of acceleration, and the effects of weightlessness had already been studied during the experiment with dog Laika in Sputnik II. The success of this flight is considered to be a close forerunner of man's travel into space. Some apparent improvements of Sputnik V upon Sputnik II are: (1) safe recovery of the spaceship and capsule were programmed; (2) behavior of the animals was televised; (3) the hermetic compartment was equipped "with everything necessary for a future manned flight to outer space;" (4) confidence in the reliability of all the automatic systems was achieved; (5) living organisms from simple to intricately organized animals were successfully flown; (6) telemetered measurements of both cosmic and solar radiation were accomplished; (7) individual dosimeters for measuring ionizing radiation were installed in close proximity to and on the clothing of the dogs; (8) metabolism and cardiovascular changes, and immunological studies, were made possible; (9) purposeful experiments to attempt to solve the problem of vitality of cells and radiogenetic safety in outer space were included; (10) for the first time, the safe flight of a variety of live creatures in outer space and their safe return to earth was realized.

h-6 Hetherington, A. W., "Biological specimens in Sputnik V," Andrews AFB, Washington, D.C., Hdqtrs. AFSC, 1961

The biological payload of the Sputnik V orbital capsule contained specimens which previously had not been placed aboard the sounding probes or ballistic shots of the U. S. An analysis of documents ("A summary of the information received on the second Soviet biosatellite - 1960 Lambda 1/Sputnik V") was made by specialists. The opinions and results of these specialists are presented.

h-7 Hixson, W. C., Paludan, C. T., and Downs, S. W., Jr., "Primate bio-instrumentation for two Jupiter ballistic flights," IRE Trans. Med. Elect. ME-7:318 (1960)

A description is given of the bioinstrumentation phase of two related Army Jupiter ballistic missile flights (BioFlight 1, Dec. 13, 1958, and BioFlight 2, May 28, 1959)

involving squirrel monkey passengers (Old Reliable and Baker, respectively), one of which (Baker) was recovered alive and in good physical condition. These flights marked the initial entry into space and successful return of a primate under ballistic flight conditions comparable to those to be encountered by man. The relationship of the instrumentation program to the biocapsule design in terms of the telemetered measurements is described. An outline is presented of the signal conditioning circuits and associated transducers used for the in-flight telemetry recording of the primate's electrocardiogram, respiration rate, chest sounds, and axilla body temperature. Instrumentation related to the recording of the ambient temperature and pressure of the biocapsule, flash temperatures, and cosmic-ray-particle tracks is also described. Data illustrations include: an excerpt from the raw telemetry record received during the free-fall portion of the Old Reliable flight, selected segments from the simultaneously occurring electrocardiogram and respiration rate signals received during the prelaunch, launch, postbooster cutoff, and free-fall periods for each animal, the respiration signal during the Baker flight shown continuously from the prelaunch through the postbooster cutoff phases to demonstrate the reliability of this measuring technique. Except for the temporary 60-second loss of the respiration-rate signal on the Old Reliable flight, all devices performed as desired for the entire telemetered flight-data period. In the case of the Baker flight, the physiological and environmental measurement channels were still in operating condition when tested aboard the recovery vessel.

i-1 Isakov, P., "Life in Sputnik," Astronautics 3:38-39, 49-50, (1958)

A Russian biologist examines problems involved in keeping a living organism alive in space and reveals Soviet approaches. The Sputnik II experiment was carried out to verify a number of theories concerning the effect of cosmic space on living beings, and to test protective devices necessary to prevent harm or even death to living beings carried in a space vehicle.

k-1 Katzberg, A. A., "Biological experiments with space probes: III. The effect of space flights on living human cells aboard the Discoverer XVII vehicle," presented at the Lectures in Aerospace Medicine Symposium at the School of Aerospace Medicine, Jan. 16-20, 1961, Brooks AFB, Texas:SAM, 1961; abstract in Konecci, E. B., "Review of January 1961 Lectures in Aerospace Medicine - USAF SAM," Santa Monica, California: Douglas Aircraft Co., 1961

Two Rose chambers were seeded with approximately 100,000 cells each. One contained synovial cells which originated from the synovial lining of a bone joint; the other was seeded with conjunctival cells from the conjunctival surface of the eyelid. The culture medium consisted of 2 cc of balanced salt solution and 10-percent horse serum. Three sets of such cultures were prepared, one for laboratory control, one for ground control at the launching site, and one for flight. A number of studies on the returned cultures are still in progress, including possible genetic changes which may be reflected in abnormal chromosomal counts and other aberrations. To date no change in genetic characteristics has been detected. This is the first known report of such studies which entailed the use of human material in a space flight and which is an essential step preliminary to actual space flight by man.

k-2 Keeshen, W., Jr., "Eye witness report on Pacific's first nose cone recovery - operation NERV," Western Aviation 40:8-10, 60 (Oct. 1960)

Report of an American newsman, who is believed to be the first to have been on the scene for any space recovery. The General Electric NERV capsule was launched on Sept. 19, 1960, to an apogee of 1200 nautical miles and was successfully recovered at the 1200-mile impact point. This launch marked three important milestones: (1) it was the first recovery of a ballistic-trajectory nose cone in the Pacific Ocean, (2) the first major firing from the Navy's new facility at Point Arguello, California, (3) the first

NASA scientific experiment from the Pacific Missile Range. The Argo D-8 rocket had never been launched before, nor was the NERV capsule ever flown on a rocket, and this was the first time that an ablative nose cone had the capability of emitting scientific apparatus for exposure to space and then retracting it for successful reentry into the earth's atmosphere. "Operational NERV went exactly according to script and followed the time-table almost to the minute - certainly to the hour."

k-3 Kistler, W. G., Jr., "Design and maintainability of the Able-Baker bio-capsules," presented at the ARS Semi-Annual Meeting, Los Angeles, California, May 9-12, 1960; New York:American Rocket Society, ARS Paper 1226-60 (1960)

The design and development program for maintenance of the monkeys Able-Baker biocapsules is described. The requirements led to completely self-contained biocapsules with a minimum of external connections to the missile. The structural requirements imposed by the missile environment and flight were similar for both biocapsules. Weight considerations were not paramount; however, space availability and configuration imposed many problems of accessibility in the design. This report includes a description of the participating organizations, the missile and its flight profile, and the bioexperiments flown.

k-4 Konecci, E. B., "Review of January 1961 Lectures in Aerospace Medicine, USAF," Santa Monica, California:Douglas Aircraft Co., 1961

Compiled to make the timely and valuable information presented during the Second Lecture Series in Aerospace Medicine promptly available to the large number of engineering and life sciences personnel. With the exception of three papers, the material was obtained from notes and photos taken during the five-day course. Speakers included de Vaucouleurs, Van Allen, Ney, von Braun, Flickinger, Crossfield, and Clamann.

k-5 Kousnetzov, A. G., "Some results of biological experiments in rockets and Sputnik II," J. Aviation Med. 29:781-784 (1958)

A brief summary of the research work investigating the effect of space flight in rockets upon living organisms in three experimental stages from the period 1949-1958, with special emphasis given to the experimental findings on Laika in Sputnik II. Initial investigation in hermetically sealed cabins rocketed to 100-210 km ensuring the protection of vital activities was following by the task of determining the possibility of separation from the rocket, with the help of a catapult, with the subsequent descent of the animal by parachute and with the help of space suits. Catapulting experiments were carried along two lines. (1) The catapulting apparatus was started at the height of 85-75 km, with the parachute opening immediately. In this case the animal's descent took more than an hour. (2) Animal catapulting was effected at 46-39 km. These experiments were not detrimental to the health or lives of the animals. The Third experimental stage, which started in 1958, launched animals in rockets to the height of 473 km, proving safe return from high altitudes in good health. Only the Sputnik could make a biological experiment possible, because it meets all the conditions of space flight. Physiological changes noted in Laika were: at the moment of orbit, heart contractions increased by three times compared with the initial frequency; the respiratory rate was from three to four times higher than the initial rate; shortly, heart contractions fell almost to the initial stage, and return to the initial stage required three times as long as that of laboratory experiments employing similar accelerations. No pathological changes were noted from ECG analysis. Cosmic-radiation effects upon physiological functions were not discovered. The positive results of these experiments are considered encouraging for future research geared to protect the life and health of man in space flights. Questions asked of the author immediately following his presentation were answered later in the day. Responses revealed: (1) no attempt was made to catapult or parachute Laika; (2) there were no experiments with

human subjects in meteorological rockets; (3) the author had no information about experiments similar to the Manhigh project; (4) there were no signs of the vagus pulse during Laika's weightlessness; (5) in the Sputnik II system, the gas composition was monitored "near the terrestial one"; (6) Laika's death was attributed to hypoxia.

l-1 Lebish, I. J., Simons, D. G., Yagoda, H., Janssen, P., and Haymaker, W., "Observations on mice exposed to cosmic radiation in the stratosphere, A longevity and pathological study of 85 mice," Military Medicine 124:835 - 847 (1959)

A study of possible biological effects of 24-hour exposure to primary cosmic radiation was carried out on 85 mice on AMFL flight 67, launched Aug. 22, 1955, from International Falls, Minnesota. Maximum altitude reached was approximately 109, 000 ft. The animals were at 80, 000 ft or above for approximately 23 hours. Analysis of the balloon trajectory indicates that the mice received collectively a total of 7, 350 thin-down hits by heavy primaries of $Z \geq 6$, of which 59 hits were by members of the calcium-iron group. Control mice on the ground were subjected to the same rigors as the experimental mice. Both the experimental and the control animals were then allowed to live out their life span. Taking into consideration the minor differences exhibited by the experimental and control animals in longevity, incidence of neoplasms, and in reproductivity and aging, there was no definite evidence that a day's exposure to light- and medium-weight primary cosmic particles in the stratosphere had any adverse long-term effect (abstract identical with abstract L-1).

n-1 NASA, Office of Public Information, "Spacecraft II (U. S. S. R.), Space Activities Summary," prepared Aug. 29, 1960, Washington, D. C.:NASA, Release No. 60-254, 1960

Vehicle launched Aug. 19, 1960, to test safety of capsule and recovery system for ultimate development of system for manned space flight. Capsule recovered on 18th orbit, Aug. 20, 1960, after traveling 437, 500 miles. Apogee 211 miles; perigee 190 miles; velocity approximately 17,000 mph; payload weight minus final stage of rocket, 10,120 lb. Capsule reported to contain two dogs and a number of rats, mice, flies, plants, fungi, microscopic water plants, and some seeds. Instrumentation included television camera to relay pictures of animals in flight, radio transmitter relaying information on condition of animals and other experiments, and "retro device" for recovery Carrier and capsule recovered less than seven miles from predetermined point. Sources: unofficial U. S. and Soviet press and radio.

n-2 NASA, Office of Public Information, "Discoverer III. Space Activities Summary," prepared Sept., 1960. Washington, D. C.:NASA, Release No. 60-278, 1960

Vehicle launched from Vandenberg AFB, California, on June 3, 1959, as a satellite system to gather data on propulsion, communication, orbital performance and stabilization, recovery techniques, measurement of radiation, and biomedical environmental research on four black mice. Preliminary telemetry indicated second stage fired, but no signals from satellite received. Orbit believed doubtful. Injected downward instead of horizontally as programmed, thus effecting flight that would probably be terminated in the Antarctic regions. Instrumentation included for data capsule to be ejected from satellite by timing devices; small retro-rocket to aid reentry; various devices to aid in locating capsule which contained the animals and environmental research devices and radiation measurement equipment. Payload 1600 lb, including second stage casing; 245 lb of instrumentation for communications and performance and 195-lb data capsule.

n-3 NASA, Office of Public Information, "Discoverer XVII. Space Activities Summary," prepared Nov. 30, 1960, Washington, D. C.:NASA, Release No. 60-303, 1960

Vehicle launched from Vandenberg AFB, California, on Nov. 12, 1960, for systems evaluation of Agena B satellite, including launching techniques, propulsion, communications, orbital performance, recovery techniques, and advanced engineering tests. Orbit achieved. Capsule ejected from orbit on Nov. 14, and snatched in mid-air by a C-119 aircraft near Hawaii. Apogee 61.6 miles; perigee 116 miles; velocity approximately 17,926 mph; payload 2,100 lb, including 2nd stage casing and 300-lb reentry capsule, retro-rocket and recovery aids. Instrumentation included reentry capsule to be ejected from satellite by timing device, retro-rocket and parachute to slow descent, radio beacon and radar chaff for recovery. Vehicle also carried a radiation counter and emulsion pack to explore radiation in lower Van Allen belts, micro-organisms, plant spores, and microscopic, artificially grown human cells, and a high-intensity light beacon for optical tracking.

n-4 NASA, Office of Public Information, "Spacecraft III (U.S.S.R) Space Activities Summary," prepared Dec. 15, 1960, Washington, D.C.:NASA, Release No. 60-321, 1960

Vehicle launched Dec. 1, 1960, to test equipment for ultimate manned space flight. Vehicle descended along uncalculated trajectory when signaled to return to earth and was destroyed in dense atmosphere Dec. 2, 1960. Apogee 155 miles; perigee 112 miles; velocity approximately 17,000 mph; payload 10,060 lb. Two-part craft reportedly carried two dogs and a variety of other animal and plant life. Instrumentation included radio and television equipment relaying information on condition of animals on board. Sources: unofficial U.S. and Soviet press and radio.

n-5 NASA, Office of Public Information, "Discoverer XVIII. Space Activities Summary," prepared Dec. 15, 1960, Washington, D.C.:NASA, Release No. 60-321, 1960

Vehicle launched from Vandenberg AFB, California, on Dec. 8(sic), 1960, for systems evaluation of Agena B satellite, including launching techniques, propulsion, communications, orbital performance, recovery techniques, and advanced engineering tests. Orbit was achieved. Capsule was successfully ejected and snatched in mid-air by C-119 aircraft near Hawaii on Dec. 10. Capsule completed 48 orbits and traveled more than 1,250,000 miles. Apogee 459 miles; perigee 154 miles; velocity approximately 17,693 mph; payload 2,100 lb including 2nd stage casing and 300-lb reentry capsule, retro-rocket, and recovery aids. Instrumentation included reentry capsule to be ejected from satellite by timing device, retro-rocket and parachute to slow descent, radio beacon and radar chaff for recovery. Vehicle also carried algae, bone marrow, membrane from underside of eyelid, gamma globulin, spores, and other material for a variety of medical and technical experiments. Included tracking experiment consisting of light beacon for SAO optical tracking.

n-6 NASA, Office of Public Information, "Sputnik II (U.S.S.R.). Space Activities Summary," prepared Dec., 1960. Washington, D.C.:NASA, Release No. 61-25, 1961

Vehicle launched Nov. 3, 1957, to place artificial satellite in earth orbit carrying experimental animal (Laika) to conduct biomedical experiments and measurement of solar radiation and cosmic rays. Satellite down Apr. 14, 1958. Apogee 1,038 miles; perigee 140 miles; velocity about 15,000 mph at apogee, 18,000 mph at perigee; payload 1,120 lb; total in orbit, including rocket body, estimated at four tons. Instrumentation was included for study of solar radiation in ultraviolet and X-ray bands, measurements of cosmic radiation, biological reactions of dog in pressurized cabin. Major results: led to discovery of first significant solar influence on upper-atmosphere densities, measured electron concentration in outer ionosphere, measured cosmic rays, provided biomedical information. Sources: unofficial Soviet and U.S. press and radio.

n-7 "Upper atmosphere research report No. 1, Part I," NRL Report 2955, p. 82, Oct. 1946; ATI 5231

"The Naval Research Laboratory is collaborating with Harvard University in sending biological specimens into the upper atmosphere. Biologists at Harvard wish to determine the effects, if any, of the radiation at high altitudes on the characteristics of seeds, eggs, etc. Particular interest attaches to the possibility of mutations. For this purpose they provided a quantity of specially developed strains of seeds, samples of which were incorporated into the July 9 and July 19 flights. Unfortunately, seeds were never recovered. During the final preparation for missile No. 9, scheduled for firing on July 30, it was noticed suddenly at White Sands Proving Ground that the Harvard supply of seeds had run out. Since by that time little hope was held for recovery of any equipment or material from a rocket after flight, no attempt was made to replenish the supply for the July 30 firing. Instead, a package of ordinary corn seeds was purchased in a Las Cruces store for inclusion in the flight. As fate would have it, the flight broke all altitude and all recovery records. The seeds which were recovered, along with some which had been withheld for a standard, have been forwarded to Harvard for analysis."

n-8 "Upper Atmosphere Research Report No. IV," NRL Report 3171, p.115, Oct. 1947; ATI 24526

"Collaborative program between Harvard and NRL continued on Oct. 10, 1946. Rye seeds provided by Harvard, containers of various types supplied by Harvard and NRL, stowed in various parts of missile." (p. 112) "Seeds recovered."

p-1 Parin, V. V., Chernigovskii, V. N. and Yazdovskii, V. I., "Some results and perspectives in research in the areas of cosmic biology," Izvestiia Akademii Nauk SSSR, Seria Biologicheskaia. 25(1):3-18 (1960); German translation in: Sovietwissenschaft: Naturwissenschaftliche Beitrage (Berlin), No. 7:677-689, July 1960

The first stage of Soviet studies in cosmic physiology consisted in launching six rockets with two dogs in each. In this experimental series the possibility was proved of animal survival in a hermetic cabin during a rocket flight to an altitude of 100 km at a velocity up to 4212 km/hr. In the second series (nine rockets with two dogs in each) it was shown that the animals can be rescued when kept in nonhermetic cabins, by catapulting from altitudes as high as 100 km, and at velocities of 700 to 725 m/sec, as well as from 50-km altitudes, and velocities ranging from 1000 to 1150 m/sec. During the flight the condition of the animals was physiologically quite satisfactory. In the third series the altitudes were increased to 200-212 km, and some details of the experiment were modified. The results were on the whole similar to those referred to previously. Similar results have also been obtained from dogs in further experiments at altitudes up to 450 km. The experiment carried out on the second artificial Soviet satellite (Sputnik II) rendered it possible to study the effect upon the organism of acceleration, noise, and vibrations from the moment of launching up to entering the orbit as well as of prolonged absence of gravitation during the orbital flight. The general conclusion to be drawn from the biological experiment on the second Sputnik is that conditions still more like those of cosmic flight than those obtained in rockets are fairly well tolerated by highly organized animals. The experiments should therefore be continued and extended still more actively. To solve the problem of the flight of the first cosmic ship with a man aboard, it is necessary to develop scientifically grounded principles of selection of people for this purpose. As to regeneration of the air, food provision, water supply, elimination of excretions, these questions are to be considered as more or less settled for relatively short cosmic flights. Prolonged journeys necessitate the development of devices which would transform the cosmic ship into a kind of a closed microcosm with its own cycle of substances.

p-2 Phillips, J. N., Jr., "Experiments with photosynthetic micro-organisms in Discoverer satellite vehicles. IV. Final report on Discoverer XVII experiments," presented at the Lectures in Aerospace Medicine Symposium at the School of Aerospace Medicine

Jan. 16-20, 1961; Brooks AFB, Texas:SAM, 1961; abstract in Konecci, F. B., "Review of January 1961 Lectures in Aerospace Medicine - USAFSAM," Santa Monica, California: Douglas Aircraft Co., 1961

Selection of photosynthetic organisms as one of the prime classes of living things requiring evaluation is based on the belief that long-term biological management of life-support logistics is more desirable and attractive than nonregenerative systems of management. Pure cultures have been placed aboard the vehicles and have been carefully analyzed subsequent to flight in a manner designed to provide objective evaluation of essential physiological functions. A selected green algea, identified as Chlorella ellipsoidea, strain SAM-127, was used in this experiment. Identical treatments and managements of both ground and laboratory vials were carried out simultaneously with evaluations of flight vials. Conclusions: (1) these organisms are capable of living and retaining viability in actual space environments; (2) none of a number of physiological responses evaluated have been detectably harmed by exposure to these environments; (3) these organisms could survive and function as part of a life-support system when exposed to radiation levels for the orbital time period of the Discoverer XVII satellite.

p-3 Pokrovskii, A. V. (Transl. by A. C. Murray), "Vital activity of animals during rocket flights in to the upper atmosphere," in Krieger, F. S. "Behind the sputniks. A survey of Soviet space science," R-311 AD 150689, Santa Barbara, California:The Rand Corp., 1957

Dogs were studied in rocket flight to the upper atmosphere in two experimental stages: (1) hermetic, and (2) nonhermetic flights. The first stage employed nine dogs (three flown twice) at speeds of 4212 km/hr, at maximum acceleration of 5.5 G, to altitudes not exceeding 100 km. The studies concluded that under the experimental conditions a low-volume (0.28 cubic meters) hermetic cabin utilizing an air regenerating system ensures the conditions necessary for the life of two dogs for three hours; complex external factors during flight cause practically no important change in the behavior and in the state of the various physiological functions of the animal and are for this reason completely endurable. The parachute system ensures safe descent and landing of the animals in the sealed compartment of the rocket.

The second stage employed 12 dogs subjected to preliminary training in space suits in a nonhermetic compartment with a volume of 0.28 cubic meters. Two dogs participated in each flight, and some animals were used twice. Experimental results in the different stages of flight reveal that no substantial changes in cardiovascular condition nor respiratory function occurred, that functional changes observed do not have a profound character and are conspicuous by their short duration; no important change in the general behavior of the animals observed. The space suits guarantee the creation and maintenance of conditions necessary for the animal's life during rocket flight of about one hour in the upper layers of the atmosphere, during the ejection, during the descent by parachute from an altitude of 85 km to the ground, and also during free fall from an altitude of 35 to 40 km. Both the ejection method and the parachute system ensured safe recovery. None of the rocket flights during either the first or the second stage of the work resulted in the death of animals through lack of oxygen or because of the influence of external factors connected with flight in the upper layers of the atmosphere.

s-1 Schocken, K., and Gerathewohl, S. J., "A quantitative evaluation of the electrocardiograms of two squirrel monkeys under changing conditions," Report No. DV-TN-12-60. Redstone Arsenal, Alabama:ABMA, 1960

The following cardiodynamic effects of changes of the gravitational force have been previously observed: (1) a marked increase in cardiac rate occurs in almost all subjects during acceleration and deceleration periods, (2) the electrocardiogram is generally normal in the zero-G state, (3) the heart rate is increased and unstable during post-acceleration weightlessness, (4) transient changes may occur in the electrocardiogram if the state of the gravitational field changes, (5) the steady cardiodynamic state seems

to be the same for zero G as for the one G condition, (6) increased G loads lead to the condition of physiological stress, (7) the absence of G-forces is a mechanically stressless condition, (8) the stresses imposed by acceleration and the condition of weightlessness encountered in aircraft and missile flights are within the range of tolerance of the human and animal organism. These cardiodynamic effects are confirmed by the electrocardiographic findings of the two bioflights of monkeys. A rigorous statistical evaluation of the limits of normality, in a similar manner as was carried out previously in humans, is possible and can be performed as soon as sufficient statistical material is available.

s-2 Simons, D. G., "Use of V-2 rocket to convey primate to upper atmosphere." AF TR-5821, Wright-Patterson AFB, Ohio:Air Material Command, 1949

The report describes the techniques and devices developed to protect a monkey during flight in the nose-section of a V-2 rocket. Results obtained from two separate flights are discussed. Each time the properly supported animal (rhesus monkey) was enclosed in a pressurized capsule containing a 24-hour oxygen supply and apparatus for carbon dioxide and water vapor absorption. Also, provisions for recording respiration and the electrocardiogram on a Cook recorder during the flight were included. The experiments are referred to as Project Albert I - included in Blossom III fired on June 11, 1948, and Project Albert II - included in Blossom IVB, fired on June 14, 1949. After installation of Albert I, nine pounds, anaesthetized, indication of neither heart action nor respiration could be obtained, due either to death of the monkey or to failure of the electrocardiographic apparatus. The rocket attained 37 miles altitude, and separation of the nose occurred as scheduled, but the parachute system failed, causing destruction upon impact. Albert II, six and one-fourth pounds, also anaesthetized, reached 85 miles altitude, but again parachute failure killed the animal upon impact. However, the animal was still alive and apparently well throughout the 340 seconds (up to a few seconds before impact) of record recovered, representing almost the entire flight. Barring parachute failure, animal recovery was considered likely. During 10 to 15 seconds of peak acceleration at 5.5 G, the per-minute decreases in heart rate and respiration were 190 to 110 and 90 to 60, respectively. The free-fall condition, lasting several minutes, was characterized by gradual decrease in pulse rate from 190 to 180 and respiratory rate from 65 to 60, suggesting a calming effect of a gravity-free environment rather than cardio-acceleration, as anticipated.

s-3 Simons, D. G., DeBusk, A. G., and Hewitt, J. E., "Bioastronautics 1959 primary cosmic radiation research program," paper presented at the Annual Meeting of the Aerospace Medical Association, April 1960, Chicago, Illinois; Brooks AFB, Texas:SAM, 1960

The techniques developed to examine the unique biological track effects produced by the high-energy heavy ions characteristic of primary galactic cosmic radiations are presented. The report includes the flight experiments conducted during 1959 and reviews related laboratory experiments. Nuclear emulsion track plates (NTB-3) were used to monitor primary cosmic particles of $Z \geq 6$ traversing biological materials exposed for 13 hours at 127,000 ft on a balloon flight, and above the atmosphere for 4-1/2 minutes on a rocket flight. The materials exposed included Neurospora crassa, HeLa cells, E. coli, rat ganglion cells, barley seeds, and flower beetle eggs. Correlation of positive results between disks impregnated with Neurospora crassa N-51 conidia spores and the corresponding track plates emphasize the importance of track-plate monitoring in the interpretation of results, and the value of combined quantitative and qualitative methods of assessing the biological effects. (Abstract identical with abstract S-20).

s-4 Sisakyan, N. M., "Biological observations of animals carried by rockets," Academy of Sciences of the USSR, No. 11. XXX:15-24 (1960)

A paper presented by N. M. Sisakyan at a conference of the USSR Academy of Sciences, which reports the experimental results of biological observations of animals during vertical rocket flights to altitudes of up to 450 km and during their safe return to earth.

s-5 Sisakyan, N. M., "Biology and cosmic flights," U. S. Joint Publications Research Service, 9479, June 19, 1961; Washington, D. C.:OTS, U. S. Department of Commerce; Translated from Priroda (Nature), Moscow, No. 1, 7-16, Jan., 1961.

Soviet accomplishments in space biology in terms of space flights to date are summarized, and the problems to be resolved for successful manned cosmic flights are discussed. Vertical rocket flights carrying animals to 450 km altitude solved certain problems of assuring safety and special recovery under special flight situations. It was demonstrated experimentally that in cases of emergency at altitudes of 78-88 km and 39-46 km, and velocities of 2000 km/hr and 4, 100 km/hr, respectively, catapulting serves as a reliable method of separating cabin from rocket without causing noticeable disorders in physiological functions; the use of visorless space helmets assures safety from altitudes of 78-85 km; the brief (three to ten minutes) effect of weightlessness caused no essential cardiovascular or respiratory changes. The effects of acceleration and deceleration were manifested in the elevation of blood pressure, an increase in pulse frequency, and certain changes in the electrocardiogram; during weightlessness these changes gradually decreased and approached the original level. After five to six minutes or at the end of the weightless period, the indices of the main physiological functions returned to the original level. The conclusion from the Laika experiment was that prolonged weightlessness does not cause substantial changes in the main physiological functions of an animal. Analogous data were obtained from the second and third cosmic satellite-ship experiments. Belka and Strelka were in a catapultable container with apparatus which registered arterial pressure, heart tone, body temperature, and motor activity. Electrocardiograms and pneumograms were recorded, and the behavior of the animals was monitored by television.

The physiological information obtained by telemetry is still not completely processed; preliminary data testifies that changes in the physiological indices did not exceed changes observed during training. In the active region of the flight, a sharp increase in pulse and respiration was noted; the frequencies decreased during the transition to weightlessness, and in one and one-half hours the pulse and respiration were comparable to preflight data. During weightlessness all physiological functions were close to the original level. Biochemical methods were employed to study the biological effect of cosmic radiation and other factors of the flight. The blood and urine of experimental dogs, rats, and mice were studied. Several days after the return of Belka and Strelka, a temporary increase was noted in the amount of alpha globulin, serum mucoid, and the total content of albumin. These investigations also showed that stable disorders of nucleic acid metabolism after the flight apparently do not occur. Biochemical investigations are presently being continued. Various living organisms, from very simple to very complex, were placed aboard the second cosmic ship to study, first of all, the genetic consequences of the radiation effect.

All the numerous cytological, genetic, and microbiological objects were returned from the flight alive. The investigations to date have not revealed any changes, including genetic, in bacteria (coliform bacteria of various strains, butyric fermentation bacteria, staphylococci) or in the several varieties of phages causing lysis of bacteria. The desoxyribonucleic acid, HeLa cell cultures, and pieces of human and rabbit skin also differed little from the control specimens. Subsequent accretion of the skin flaps which had been in cosmic space did not differ from accretion of the control ones. The automatic bioelements with the bacteria cultures of butyric fermentation operated during the flight in complete conformity with the program and attested to the normal activity of the microbes. The "flight" mice are being subjected at present to histologic, cytologic, and genetic investigations. Their marrow, testes, spleen, thymus, and other organs are being investigated, but it is premature to make final conclusions from this analysis. A study of Drosophila did not show any genetic effect of the cosmic flight. It is concluded that the biological experiment carried out on the second satellite-ship undoubtedly is unique in its results.

s-6 Stroman, G. S. and Lewis, T. H., "A study of genetic affects of cosmic radiation on cotton seed," J. Heredity. XLII:211-213 (1951)

Samples of seed from individual cotton plants known to be heterozygous for certain seedling defects were exposed to high-altitude radiation in an experimental V-2 rocket. An altitude of 90.5 miles was reached during a 595.5-second flight (Nov. 18, 1948). The exposed seed was grown through the second generation against controls from the same parent plants. Changes noted in the radiated material remain to be finally evaluated and cannot as yet be designated as cosmic radiation effects.

u-1 United States National Aeronautics and Space Administration in cooperation with National Institutes of Health and National Academy of Sciences, "Proceedings of a conference on results of the first U. S. manned suborbital space flight," June 6, 1961, Washington, D. C., Superintendent of Documents, U. S. Government Printing Office.

The papers presented, including a pilot's flight report, were prepared by representatives of the NASA Space Task Group in collaboration with personnel from various Department of Defense medical installations, the University of Pennsylvania, and McDonnell Aircraft Corporation.

v-1 Van der Wal, F. L., and Young, W. D., "A preliminary experiment with recoverable biological payloads in ballistic rockets. Project MIA," Los Angeles, California:Space Technology Laboratories, 1958

The project, known as Project MIA (Mouse-In-Able), was planned as a noninterference experiment in conjunction with the Project Able reentry test program. In each of the three Able flights, one mouse was carried in the nose cone. Although none of the nose cones were recovered, telemetered physiological records were obtained on the second and third Able flights. This report includes a detailed description of the physical system, of the preliminary tests and flight preparations, of the instrumentation used in flight, and the resulting signal pattern. The special problems associated with the use of living payloads in space flight vehicles are also discussed.

v-2 Van der Wal, F. L., and Young, W. D., "Project MIA (Mouse-in-Able), Experiments on physiological response to spaceflight," ARS Journal pp. 716-720, Oct. 1959

This project was planned as a noninterference experiment in conjunction with the Project Able reentry test program employing as the launching vehicle a two-stage missile consisting of the Douglas Thor IRBM and the Aerojet 1040 liquid propellant rocket. Three Able vehicles were flown: April 23, July 9, and July 23, 1958. Each carried a mouse. Although none of the nose cones was recovered, telemetered physiological records (heart rate) were obtained on the second (for mouse Laska) and third (for mouse Benji) flights. The amount and nature of the data available were extremely limited, and therefore no generalized conclusions regarding the behavior of space mice could be drawn. Among the observations were the following. (1) Take-off conditions were not severe enough to produce any evidence of violent or continuing response from the mice. (2) The acceleration loads during burning were essentially paralleled by Laska's heart rate, though this characteristic was not displayed by Benji under similar load conditions. (3) The observed decrease in Laska's heart rate at first-stage burnout was gradual; at second-stage burnout it was sharp. This is in opposition to the heart-rate behavior reported for Laika, the Russian satellite dog. No trend was detectable in Benji's heart rate at first-stage burnout, but a distinct increase to slightly above his preflight reading was apparent at the beginning of weightlessness. (4) Since both mice flew to a maximum altitude of 1400 statute miles (as compared with Laika s apogee of 1050 miles), they returned to earth from a higher altitude than that reached by any other living organism. (5) Laska, and probably Benji, returned to sea level alive after experiencing reentry conditions approaching those associated with satellite reentry.

(6) No evidence of distress due to weightlessness was noted in either flight. The mice were weightless for longer periods than any animal other than Laika. (7) There is every reason to believe that both Laska and Benji would have been recovered alive after their flights if the nose cones had been retrieved.

The report includes a description of the physical system, the preliminary tests, development of the instrumentation used in flight, and the resulting signal pattern. The special problems associated with the use of living payloads in spaceflight vehicles are discussed.

w-1 Wilbarger, E. S., "Biomedical measurements in ballistic missiles," special report, CSCRD-16-3, Washington, D. C.:USAMRDC, Headquarters, Office of the Surgeon General, 1959

Preparation for the first flight of a primate (Old Reliable) in a ballistic missile is described. Limitations imposed by conditions of flight are outlined. The animal container is described; physiological measurements are noted, and the circuits and transducers for physiological measurements are described. Two sets of photographic emulsion plates were installed inside the capsule to record cosmic ray activity. Also included in the capsule were several heat-sensitive paper indicators.

y-1 Yazdovskiy, Y. I., "Biological experiments on rockets and artificial earth satellites," paper presented at the Rocket and Satellite Symposium during the Fifth Reunion of the Comite Special Annee Geophysique Internationale, Moscow, July 30-Aug. 9, 1958; Washington, D. C.:National Academy of Sciences, National Research Council

Summarizes succinctly the purposes and results of Soviet rocket investigations with animals in three experimental stages. Major emphasis is given to the experimental results of the orbital flight of dog Laika, in Sputnik II.

y-2 Young, R. S., and Johnson, J. L., "Basic research efforts in astrobiology," paper presented under the title, "Design Criteria for Instrumentation to Investigate Biological Space Flight Effects," at the Instrument Society of America Meeting at Chicago, Illinois, on Sept. 23, 1959; Moffett Field, California:NASA, Ames Research Center

The special problems involved in performing basic biological experiments in space vehicles are presented, emphasizing the need for unique types of instrumentation. Some of the techniques used in preliminary experiments in recoverable nose cones of Army ballistic missiles are discussed in some detail. The reasons for doing this type of research in these vehicles are also discussed.

y-3 Young, R. S., "Biological experiments on Jupiter AM No. 23," Moffett Field, California:NASA, Ames Research Center (not dated)

Available space on Jupiter AM No. 23 was utilized to conduct basic biological experiments in an attempt to answer questions pertaining to the effects of various flight parameters (e. g., weightlessness, cosmic radiation, increased gravity-load) on cellular systems and intact organisms. These experiments included Neurospora, human blood sample, E. coli sample, onions and mustard seeds, Drosophila pupae, sea urchin eggs, algae cells (Chlamydamonas), tissue culture of human skin, two frogs, and several pregnant mice.

y-4 Young, R. S., and Johnson, J. L., "Basic research efforts in astrobiology," Paper presented at AAS Meeting, Jan. 18-21, 1960, New York; Redstone Arsenal, Alabama: ABMA, Development Operations Division, Research Projects Laboratory, Dec. 7, 1959

A brief summary of the experimental purposes, techniques, and some preliminary results pertaining to the effects of weightlessness and cosmic radiation on living systems in Jupiter flights 13, 18, and 23. Biological payloads included Neurospora spores, human blood, the bacterium, E. coli, onions, mustard and corn seeds, Drosophila pupae, yeast, sea urchin eggs and sperm, algae cells, tissue cultures of human and frog skin, and pregnant C-57 black mice. Not all experiments were concluded, due to one nose-cone recovery failure, one unsuccessful flight, and, in certain instances, insufficiencies in experimental design.

y-5 Young, R. S., "Basic research in astrobiology," paper presented at the AAS Meeting, Jan. 18-21, 1960, New York, N. Y.; Redstone Arsenal, Alabama:ABMA, Development Operations Division, Research Projects Laboratory.

The need is stressed for developing the ultimate in biological systems for answering all the questions surrounding the human in space flight: radiation, weightlessness, and environment. In relation to the possibility of life on other planets, a second approach through more basic study of biology and biophysics, such as the origin of life, is also emphasized. Also, a technique is described for the fertilization of sea urchin eggs during flight.

y-6 Yugov, Y. and Serov, A., "Before man's flight into space," translations from the Soviet Press, No. 553, Washington, D. C.:Embassy of the USSR, Nov. 5, 1958

Outlines both biological problems solved and yet to be resolved for manned rocket space flights and summarizes briefly some accomplishments of Soviet space biology, which include some Sputnik II findings and some results of preceding investigations on animal-carrying rocket flights.

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CHAPTER IV

BIOMEDICAL EXPERIMENTS ON HIGH-ALTITUDE ROCKET-RESEARCH AIRCRAFT: THE X-15 PROGRAM

INTRODUCTION

The winged, rocket-powered experimental aircraft presents another approach to man's striving for altitude and speed. During the earlier flights, survival was the main criterion of a successful flight. In-flight physiological monitoring of the X-15 pilot was initiated on May 5, 1960. By the end of that year, thirteen flights of aircraft No. 670 and three flights of aircraft No. 671 were physiologically monitored, with data obtained from all seven pilots engaged in the X-15 program. A review of these data revealed no detrimental effects of the flight stress at present. Future achievements of the rocket-powered aircraft, including orbital flight, may be expected (Tables 1 and 2).

Table 1
Major Achievements of Experimental Rocket Aircraft and Operational Jet Aircraft Up To The Year 1960

Date	Pilot	Airplane	Speed (mph)	Altitude (ft)
Experimental Rocket Aircraft				
Oct. 14, 1947	Ch. E. Yeager	Bell X-1	760 (Mach 1.06)	---
1948	---	Bell X-1	967	60,000
1949	---	---	---	70,140
Aug. 15, 1951	W. Bridgeman	Douglas D-558-11 Skyrocket	1238	79,494
Aug. 21, 1953	M. Carl	Douglas D-558-11 Skyrocket	---	83,235
Nov. 21, 1953	S. Crossfield	Douglas D-558-11 Skyrocket	1327	60,000
Dec. 12, 1953	Ch. E. Yeager	Bell X-1A	1650	70,000
1954	A. Murray	Bell X-1A	---	90,000
July 1956	F. K. Everest	Bell X-2	1900	---
Sept. 7, 1956	I. C. Kincheloe	Bell X-2	---	126,000
Sept. 27, 1956	M. G. Apt	Bell X-2	2200 (Mach 3.3)	75,000
Aug. 4, 1960	J. Walker	X-15	2196	---
End 1960 - X-15 most likely surpassed previous altitude and speed records.				
Operational Jet Aircraft				
May 7, 1958	H. Johnson	Lockheed F104-A	---	91,244
Dec. 6, 1959	L. Flint	McDonnell F-4H	---	98,556
Dec. 14, 1959	J. Jordan	Lockheed F-104C	---	103,389

NOTE: Dashes indicate data not available.

Table 2
Flight Summary of X-15 Flights in 1959 and 1960

Character of Flight	Aircraft No. 670	Aircraft No. 671	Both Aircraft
Number of flights Captive	14	11	25
Glide	1	0	1
Powered	18	12	30
Time range of free-flight periods	5 to 12 min	7 to 12 min	5 to 12 min
Time range of captive-flight periods	31 min to 1 hr 45 min	37 min to 1 hr 43 min	31 min to 1 hr 45 min

Pilots: Scott Crossfield, Joe Walker, Bob White, Forrest Petersen, Jack McKay, Bob Rushworth, and Neil Armstrong.

GENERAL INFORMATION

Bridgeman, W., and Hazard, J., "The Lonely Sky," New York:Henry Holt, 1955

"Jane's All The World's Aircraft 1954-1955," New York:McGraw Hill, 1954

"Jane's All The World's Aircraft 1957-1958," New York: McGraw Hill, 1957

"Jane's All The World's Aircraft 1960-1961," New York:McGraw Hill, 1960

Ley, W., "Rockets, Missiles and Space Travel," New York:The Viking Press, 1957

Lundgren, W.R., "Across the High Frontier: The Story of a Test Pilot - Major Charles E. Yeager, USAF," New York:William Morrow, 1955

"The Aerospace Yearbook 1960" (41st annual edition), Washington, D. C. :American Aviation Publications, Inc., 1960

ANNOTATED BIBLIOGRAPHY

1 Anonymous, "Bell X-1A," J. British Interplanet. Soc. 12:233 (1953)

Short notice on technical data of the aircraft.

2 Crossfield, A.S., "My journeys toward the stars," Sat. Eve. Post pp. 20-21, 82, 84-86, Feb. 20, 1960; pp. 97, 100-102, Feb. 27, 1960

The test pilot of the X-15 discloses the never-before-told story of his experiences. The X-15 manned space program was conceived with the object of building a piloted aerospace-ship to be flown in and out of the earth's atmosphere. It is an outgrowth of the X-1, X-2 and D-558-11 experimental rocket-research airplanes, and is, in effect, the prototype of future spaceships which can be flown from the earth to manned satellite platforms and return, or from these satellite platforms to other planets. Launched at 40,000 ft from a B-52 mother plane, the X-15 is designed to fly at over 4,000 mph and to over 100 miles altitude. With more exotic fuels and a more powerful engine, it can be flown to a 500-mile altitude and 7000 mph. With reentry heat protection of the fuselage skin, and with a more effective launching platform, such as an Atlas missile or B-70 bomber, the X-15 could be flown into an 18,000-mph orbit about the earth. Since the time of trucking to Edwards AFB, the X-15 has been taken aloft fourteen times and dropped four times, once for a power-less glide landing and three times for powered flight. One of the three powered flights was considered a complete success. The other two, which yielded considerable valuable data, were marred by malfunctions.

3 Goldberg, M.N., Mills, R.A. and Blockley, W.V., "Instrumentation package for in-flight physiological studies," WADC TR-60-83, Wright-Patterson AFB, Ohio: USAF, ARDC, AML, 1960

An instrumentation package has been developed for the monitoring of pilot physiological status during flights in the X-15. Data recorded include electrocardiograph signals, respiratory flow rates, skin and deep-body temperatures, and helmet-suit and suit-cockpit pressure differentials. Environmental and flight tests were performed to determine the characteristics of the package and to survey subject response during stress. The package is capable of driving a pulse-duration-modulation system for telemetering pressure data. Descriptions of the components and method of use are included.

4 Rowen, B., "Biomedical monitoring of the X-15 program," AFFTC-TN-61-4, Edwards Air Force Base, California; USAF, ARDC, May, 1961

The techniques of air-to-ground telemetry have been used in research-aircraft testing since the X-1 program in 1946. It became apparent through the development of the X-type research aircraft that personnel responsible for aeromedical support of the pilot were not taking full advantage of the developments in telemetry systems to monitor the pilot medically during flight. This document identifies and describes the techniques used, the results obtained, and the future potential of biomedical monitoring as applied to the X-15 research aircraft flight demonstrations. The inflight and real-time systems used for on-board recording and air-to-ground telemetry are described. Helmet vs suit pressure and suit vs cockpit pressure are telemetered to the ground in real time on a routine basis. On-board oscillograph recordings of respiratory rates, body temperatures, and electrocardiographic data are also obtained routinely. A quantitative analysis is presented. As an encouraging trend, it would appear that heart and respiratory rates of a pilot's second flight are considerably reduced when compared with his first. Additional parameters in the X-15 physiological instrumentation program will include blood pressure, respiratory volume, radiation, and partial pressures of oxygen and carbon dioxide in the helmet. From a review of the biomedical information available, it appears that no physiological barrier to manned space flight exists.

5 Rowen, B., "Human-factors support of the X-15 program," in Gantz, K.F., "Man in Space: The United States Air Force Program for Developing the Spacecraft Crew," New York: Duell, Sloan and Pearce, 1959

Primary research interest in the X-15 program is to obtain (1) knowledge of actual flight conditions beyond the earth's atmosphere, (2) information on aerodynamic heating, heat-transfer rates, and their effects on aircraft structure; (3) quantitative physiological data during actual flight, (4) knowledge of missions involving exit from and reentry into the earth's atmosphere, (5) man's reaction to space flight. The aeromedical support mission is described briefly in terms of physiological telemetry, technique of determining whole-body cosmic radiation, simulation and training, protective equipment, and escape system.

* * *

APPENDIX 1

LIST OF ABBREVIATIONS

ABMA	Army Ballistic Missile Agency
ACEL	Air Crew Equipment Laboratory
AFBMD	Air Force Ballistic Missile Division
AFCRL	Air Force Cambridge Research Laboratory (now AFCRC)
AFFTC	Air Force Flight Test Center
AFIP	Armed Forces Institute of Pathology
AFMDC	Air Force Missile Development Center
AFMTC	Air Force Missile Test Center
AFSC	Air Force Systems Command
AID	Air Information Division
AMFL	Aero Medical Field Laboratory
AML	Aero Medical Laboratory
AMRL	Army Medical Research Laboratory
AOMC	Army Ordnance Missile Command
ARDC	Air Research and Development Command
ARS	American Rocket Society
ASTIA	Armed Services Technical Information Agency
AU	Air University
HADC	Holloman Air Development Center
HAFB	Holloman Air Force Base
HQARDC	Headquarters, Air Research and Development Command
NAAS	Naval Auxiliary Air Station
NADC	Naval Air Development Center
NAMC	Naval Air Material Center
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NIH	National Institutes of Health
NRC	National Research Council
NRL	Naval Research Laboratory
ONR	Office of Naval Research
OTS	Office of Technical Services
SAM	School of Aviation (Aerospace) Medicine
USAFSAM	U. S. Air Force School of Aviation Medicine
USAMRDC	U. S. Army Medical Research and Development Command
USNSAM	U. S. Naval School of Aviation Medicine
WADC	Wright Air Development Center (now WADD)
WADD	Wright Air Development Division
WRI	Winzen Research, Incorporated

* * *

APPENDIX 2

INDEX OF BIOLOGICAL MATERIALS EMPLOYED IN SPACE-FLIGHT EXPERIMENTS

BIOLOGICAL ARRANGEMENT

Seeds

- Angiosperms
  - Brassica hirta Moench B-2
  - Lilium amibile Palibin B-2
  - L. pumilum DC B-2
  - L. regale Wils B-2
- Barley E-3; H-4; S-20; s-3
- Batuna h-5
- Corn B-2; H-4; h-5; h-6; n-7; y-4
- Cotton s-6
- Maize a-7
- Mustard y-3; y-4
- Nigella a-7; h-5; h-6
- Onion H-4; a-7; h-5; h-6
- Pea a-7; h-5; h-6
- Radish B-2; H-4; S-8; S-24
- Rye B-2
- Snapdragon H-4
- Wheat a-7; h-5; h-6

Algae
- Algae cells c-3; k-4; y-4
- Chlamydamonas y-3
- Chlorella S-22; a-7; h-5; h-6; p-2

Plants and Parts of Plants
- Leaves S-22
- Onions S-3; y-3; y-4
- Tradescantia a-7; h-5; h-6

Fungi and Molds
- Actinomycetes a-7; h-5; h-6
- Clostridium c-4; d-1; k-4
- Neurospora H-4; S-6; S-20; S-22; S-24; c-4; d-2; d-3; s-3; y-3; y-4
- Yeast y-4
- Fungus Spores M-1; S-27; f-3; k-4

Bacteria S-20; S-22; a-7; h-5; h-6; s-3; y-3; y-4

Bacteriophage a-7; h-5; h-6

Drosophila H-4; J-1; P-2; S-24; S-27; a-7; h-5; h-6; y-3; y-4

Fish (Goldfish) H-4

Frogskin y-4

Eggs
- Artemia salina E-1; E-2; H-4; S-6; S-24
- Chicken (fertilized) H-4
- Flower Beetle S-20; s-3
- Grasshopper H-4; S-6; S-24
- Mosquito S-22
- Sea Urchin (including sperm) y-3; y-4; y-5

NOTE: This list includes only those materials subjected to flight.

Mammals (excluding humans)
  Cats C-2; H-4; S-3
  Dogs H-4; a-2; a-3; a-5; b-1, c-2; g-1; h-3; h-4; h-5; h-6; k-5; p-1; y-1
  Guinea Pigs C-5; H-4; S-6; S-7; S-24
  Hamsters C-1; C-2; S-2; S-3; S-7; S-8; S-24
  Mice C-3; C-4; C-5; C-6; H-2; H-4; L-1; S-2; S-3; S-4; S-6; S-7; S-8; S-22; S-24; a-6; a-7; c-3; d-4; h-1; h-2; h-5; h-6; k-4; 1-1; v-2, y-3, y-4
  Primates H-1; H-4; S-7; S-8; S-22; S-24; c-1; g-2; g-4; g-5; h-1; h-2; h-7; s-1; s-2; w-1; y-4
  Rabbits H-4; S-8; S-24; h-5
  Rats H-4; S-8; S-24; h-5; h-6
  Dog Skin E-2
  Mouse Skin E-2
  Rabbit Skin a-7; h-5; h-6
Humans A-3; A-4; A-9; B-1; G-2; K-1; P-1; R-1; R-5; R-6; R-7; S-1; S-9; S-10; S-11; S-14; S-16; S-23; S-26; W-3; W-4; W-5; W-6; W-7; W-8; W-9; W-10; Y-1; a-11; u-1
  Human Blood c-3; c-4; k-4; y-3; y-4
  Human Skin E-1; E-2; a-7; h-5; h-6; y-3; y-4
Cultures
  Bone Marrow Cells (human) S-22; k-4
  Cancer Cells (HeLa) S-20; S-22; a-7; h-5; h-6; s-3
  Conjunctive and Synovial Cells c-4; k-1; k-4
  Tissue E-2; H-2; H-3; H-4; S-6; S-24; k-4
Biochemical Substances
  Egg Albumin H-4
  DNA a-7; h-6
  DNA from goiter gland of a calf h-5
  Nucleic Acid h-5

ALPHABETICAL ARRANGEMENT

Actinomycetes a-7; h-5; h-6
Algae cells c-3; k-4; y-4
Artemia salina eggs E-1; E-2; H-4; S-6; S-24
Bacteria S-20; S-22; a-7; h-5; h-6; s-3; y-3; y-4
Bacteriophage a-7; h-5; h-6
Barley seeds E-3; H-4; S-20; s-3
Batuna seeds h-5
Bone Marrow Cell cultures (human) S-22; k-4
Brassica hirta Moench seeds B-2
Cancer Cell (HeLa) cultures S-20; S-22; a-7; h-5; h-6; s-3
Cats C-2; H-4; S-3
Chicken eggs (fertilized) H-4
Chlamydamonas y-3
Chlorella S-22; a-7; h-5; h-6; p-2
Clostridium c-4; d-1; k-4
Conjunctive and Synovial Cell cultures c-4; k-1; k-4
Corn seeds B-2; H-4; h-5; h-6; n-7; y-4
Cotton seeds s-6
DNA a-7; h-6
DNA from goiter gland of a calf h-5
Dog Skin E-2
Dogs H-4; a-2; a-3; a-5; b-1; c-2; g-1; h-3; h-4; h-5; h-6; k-5; p-1; y-1
Drosophila H-4; J-1; P-2; S-24; S-27; a-7; h-5; h-6; y-3; y-4

Egg Albumin H-4
Fish (Goldfish) H-4
Flower Beetle eggs S-20; s-3
Frogskin y-4
Fungus Spores M-1; S-27; f-3; k-4
Grasshopper eggs H-4; S-6; S-24
Guinea Pigs C-5; H-4; S-6; S-7; S-24
Hamsters C-1; C-2; S-2; S-3; S-7; S-8; S-24
Human Blood c-3; c-4; k-4; y-3; y-4
Human Skin E-1; E-2; a-7; h-5; h-6; y-3; y-4
Humans A-3; A-4; A-9; B-1; G-2; K-1; P-1; R-1; R-5; R-6; R-7; S-1; S-9; S-10; S-11; S-14; S-16; S-23; S-26; W-3; W-4; W-5; W-6; W-7; W-8; W-9; W-10; Y-1; a-11; u-1
Leaves S-22
Lilium amabile Palibin seeds B-2
L. pumilum DC seeds B-2
L. regale Wils seeds B-2
Maize seeds a-7
Mice C-3; C-4; C-5; C-6; H-2; H-4; L-1; S-2; S-3; S-4; S-6; S-7; S-8; S-22; S-24; a-6; a-7; c-3; d-4; h-1; h-2; h-5; h-6; k-4; v-2; y-3; y-4
Mosquito eggs S-22
Mouse Skin E-2
Mustard seeds y-3; y-4
Neurospora H-4; S-6; S-20; S-22; S-24; c-4; d-2; d-3; s-3; y-3; y-4
Nigella seeds a-7; h-5; h-6
Nucleic Acid h-5
Onion seeds H-4; a-7; h-5; h-6
Onions S-3; y-3; y-4
Pea seeds a-7; h-5; h-6
Primates H-1; H-4; S-7; S-8; S-22; S-24; c-1; g-2; g-4; g-5; h-1; h-2; h-7; s-1; s-2; w-1; y-4
Rabbit Skin a-7; h-5; h-6
Rabbits H-4; S-8; S-24; h-5
Radish seeds B-2; H-4; S-8; S-24
Rats H-4; S-8; S-24; h-5; h-6
Rye seeds B-2
Sea Urchin eggs (including sperm) y-3; y-4; y-5
Snapdragon seeds H-4
Tissue cultures E-2; H-2; H-3; H-4; S-6; S-24; k-4
Tradescantia a-7; h-5; h-6
Wheat seeds a-7; h-5; h-6
Yeast y-4

* * *

Office of Naval Research Report ACR-64. USNSAM Monograph 5. ANIMALS AND MAN IN SPACE - A CHRONOLOGY AND ANNOTATED BIBLIOGRAPHY THROUGH THE YEAR 1960, by D. E. Beischer and A. R. Fregly, 101 pp., Jan. 1962.

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